100 BOOKS SCHEME

THINGS AROUND US SERIES

270

SILK

(Natural and Artificial)

PUBLISHED BY:
THE LOTUS TRUST,
BOMBAY.

Re. 1-

Published by

THE LOTUS TRUST
Kodak House, Hornby Road,
BOMBAY.

COMPILED
by
M. H. KANTAWALA
"100 BOOKS SCHEME"
KODAK HOUSE,
HORNBY RD.,
BOMBAY

Printed by DHIRUBHAI DALAL
at the Associated Advertisers &
Printers Ltd
505, Arthur Road, Tardeo, Bombay 7

THINGS AROUND US SERIES.

HUNDRED BOOKS SCHEME.

During my student days and several subsequent journeys in Europe, I tried to find out what it was which gave the people of Europe an advantage over us. I was anxious to ascertain this more particularly because I was, from my observation, firmly convinced that the Indian mind was quick and subtle and, type for type, the Indian was more capable than the European. I discovered that there were two factors which gave special advantage to the people of Europe. One was the availability of books on technical subjects—elementary, middling and advanced—at very low prices, and the other was the existence of evening and night classes in technology in most of the cities of Europe, which people engaged during the day could attend in order to advance their knowledge in one or other subject, in which they were interested. Whereas in India a man, who was recommended for the job of a liftman, would be still found there after ten years, in Europe such a man would pick up elementary books on mechanics and electricity, read them during his leisure time, attend evening classes, add to his knowledge and then get on to a job requiring superior knowledge. From this point onwards again, he would, by the same process, try to add both to his knowledge and status as well as self-respect and earnings.

In India there are no books on technical subjects in most of the vernacular languages, with which alone people are familiar. There may be isolated productions of very elementary character, or of very advanced character, on some subjects in some of the languages. But we took a full range of topics and enquired and we found that there was no systematic series of deliberately prepared books giving useful information and a chance to a man to system-

atise his general knowledge. It is to make up this deficit in the requisite equipment in India that this scheme has been prepared In eight vernaculars in India, illustrated books on technical subjects, compiled with great care and bringing up-to-date information on the topics dealt with, would be brought out. They would be prepared on a uniform basis and there would be cross references and index volumes attached to the series

The knowledge is not new. It is extant in the English language, in which there are many books available at 6d, 9d., 1s. 0d, 2s 6d and 5s. 0d and more. These books are available only to readers in the English language, but they are written abroad and without specific reference to Indian conditions, whereas our intention is to have these books prepared carefully and wherever possible these books prepared carefully and wherever possible to bring in as many known facts relating to the subject from the Indian point of view, so as to make the book more useful to the Indian reader.

This is a task, which should have been performed by Government either in the Centre or in each respective Province. It is a task, which could have been handled satisfactorily by the various Universities in India But it is an omission, which has very far-reaching consequences in the life of the people, and it was considered desirable by the Trustees of the Lotus Trust that this work should be attempted independently and carried through so far at least as the preliminary compilation of the books and the preparation of the necessary picture blocks was concerned This work is indeed costly and for this purpose the Lotus Trust has set aside a sum of Rs. 25,000, a contribution of Rs 18,000 was received from the Trustees of Sir Dorab Tata Trust, which is gratefully acknowledged The translation in various provincial languages in India and the publication of these books in thousands of copies at a very cheap price, if possible, of about 4 annas, or a figure well within the reach of the poorest, is a task, which will still require finance and co-operation of a wide range, both official and non-official Encouragement in the form of a money grant to the scheme has already been received from the Govern-

ment of India. Considerable progress has been made in the work of compilation.

Since this work was begun in the middle of 1944, some fifty out of a hundred and ten subjects have been already dealt with and others are in the process of compilation. The list of the subjects is elastic and some topics may be dropped out and others added to.

This series does not aim merely at benefiting boys in the teen age, who are attracted towards a subject. The series is also intended to benefit workmen and staff, who are engaged in industry and who desire to know more about the activity, from which they are deriving their livelihood. It is also intended to benefit University students and, above all, to benefit the general reader who wants to add to his knowledge on one or more topics. Many men know loosely many things about many subjects, but the knowledge is not systematic and it is derived frequently from hearsay. Many men would like to know fully about subjects, which attract their notice. The series would also be an invaluable addition to school libraries and, it is hoped, would help in raising the standard of general knowledge of vernacular teachers.

The growth of industry in India has been considerable in the manufacture of some articles and altogether negligible with regard to others; the spread of knowledge covering the whole field of "THINGS AROUND US" will doubtless stimulate interest in those things, which have hitherto failed to receive attention from entrepreneurs.

Another set of people, who, we expect, would benefit from this series when it is available in every Indian language, would be workmen, who have been rendered literate by the efforts of the State Adult literacy is in the forefront of the national programme and it is our intention to make available something in which the grown-up man can find interest The active worker, when he just begins to read, should have the chance to peruse in print the topic, in which most of the things are known to him by actual work.

Another object of this series is to remove the libel on the Indian workmen and the Indian humanity generally, that there are few inventions in India. This is entirely due to the accident that improved machines are brought from abroad and even when the Indian handles them and repairs them, he has not a vivid mental picture of the whole process or the whole purpose. Once the Indian workman has full knowledge of the industry in which he is engaged, I am confident that the Indian mind is capable of inventions, which will astound the world India must stop importing in the mass equipment from abroad except sample models, and the illiteracy of the workman and the peasant must be liquidated. The effective spread of knowledge through the books compiled in this Series in all Indian languages would then bear fruit; the farmer will cease to be conservative and the workman will have the courage and good sense to make suggestions involving greater convenience for himself and leading to improvement of the process and of the machines

MANU SUBEDAR,
Chairman,
The Lotus Trust.

Kodak House,
Hornby Road, Bombay
1st March, 1948.

100 BOOKS SCHEME.

Topics on which compilation is completed

1. Rubber
2. Coconuts
3. Lighting Materials
4. Cotton
5. Wool
6. Rivers
7. Mountains
8. Sea
9. Ships
10. Light
11. Astronomy
12. Geology
13. Soils
14. Flowers
15. Fruits
16. Foodgrains
17. Seeds and Kernels
18. Vegetable Oils
19. Mineral Oils
20. Coal
21. Tobacco
22. Coffee
23. Fibres
24. Motor Car
25. Paper
26. Non-Ferrous Metals
27. Insects
28. Precious Stones
29. Plastics
30. Matches
31. Bee-keeping
32. Stone
33. Silk and Art Silk
34. Noble Metals
35. Gums and Resins
36. Roads
37. Power
38. Watches and Clocks
39. Microscope
40. Air Conditioning
41. Meteorology
42. Telegraph and Telephone
43. Photography
44. Dyestuffs
45. Glass
46. Sugar

Topics on which compilation is progressing

1. Tea
2. Salt
3. Soaps
4. Inks
5. Cement
6. Manures
7. Colloids
8. Condiments
9. Architecture
10. Aeroplane
11. Radio
12. Nutrition
13. Sanitation
14. Care of children
15. Anthropology
16. Fisheries
17. Geography
18. Irrigation
19. Machine tools
20. Workshop
21. Minerals
22. Archaeology
23. Block Making
24. Printing Press
25. Boilers
26. Mechanics
27. Cinematography
28. Disinfectants
29. Electricity
30. Explosives
31. Internal Combustion Engines
32. Perfumes
33. Musical Instruments
34. Paints and Varnishes

Topics on which compilation is not yet taken in hand

1. Iron and Steel
2. Timber
3. Leather
4. Furniture

5 Type Foundry
6 Forests
7 Agriculture
8 Animal Husbandry
9 Food Preservation
10. Public Health
11. Market Gardening
12 Knitting and Sewing
13 Cookery
14 Nursing
15 Laundry
16 Cleanliness
17. Typewriters & Comptometers
18 Pencils & Crayons
19. Cotton Textiles
20 Pottery and Ceramics
21. Abrasives
22. Ice & Aerated Waters
23 Book Binding
24 Chemistry
25 Botany
26 Zoology
27. Biology
28 Physics
29 Physiology
30. Railroad
31. Public Works
32 Armaments
33. Pictures & Picture Frames
34 Carpets
35 Fountain Pens
36 Carpentry
37. Fire-fighting Equipment
38 Drawing Materials
39. Buttons

(Contributions or co-operation from scholars and others interested in these topics would be welcome.)

SILK

CHAPTER I

INTRODUCTORY

Natural Silk

Silk is a fibrous substance produced by certain insects in the form of **cocoons** or coverings woven by them around themselves when they are undergoing transformations at a certain stage of their career. These cocoons serve to protect them when they are lying dormant within and, being woven by the insects in one continuous filament, are unwound and utilised by man in the manufacture of silken fabrics and yarn. Though many varieties of insects produce cocoons and there are other creatures like spiders which form webs and nests of silk, real silk is derived from the cocoons of the **silk-moth** which feeds on **mulberry** leaves. There are some species of silk moths which feed on different plants and their cocoons, as we shall see, yield a much inferior fibre. The art of rearing silk worms and cultivating plants on which they feed is known as **Sericulture.**

Artificial Silk

Silk being a fibre, attempts were made from time to time to produce artificially a fibre which would be equal in lustre and strength to the article supplied by Nature. The question of imitating insects in producing a thin continuous thread was not difficult as it could be forced through a tiny orifice; but the substance to be used for such forcing was a knotty problem. Various raw materials including casein, gelatine, egg albumen, agar agar and even glass were tried, but none of them proved as successful as **cellulose** which is the chief constituent of vegetable fibre. Cellulose forms the framework of plant organisms and is

found in the stems or trunks of all trees or in the seedhairs of cotton, and can, after suitable processing, be formed into a viscous solution from which filaments of artificial silk or rayon are drawn and solidified, as we shall describe fully in the fourth chapter. Another new synthetic fibre known as **Nylon** has been recently developed from coal, water and air.

Properties of Rayon

Although artificial silk is now produced in grades or qualities which to the layman appear undistinguishable from real silk, there are certain well-marked differences. Thus, artificial silk being composed of comparatively thick filaments has a more brilliant and more metallic or glossy lustre, though in modern practice dull lustre yarns are also produced by special methods. A portion of this lustre becomes permanently destroyed when boiled in water or soap solutions for sometime, unlike natural silk. Again artificial silk has a harsher, stiffer and colder feel than real silk and is more easily creased. While the strength of the breaking load of artificial silk is about half that of real silk, it becomes greatly reduced when wetted, whereas silk is only slightly effected by wetting. Further, artificial silk is not very elastic so that after being stretched it does not recover its original dimensions: in fact, 'for half its breaking strain it acts like elastic and thereafter like perished rubber'. Special machinery is therefore necessary for the weaving of rayon fabrics. The power of covering up the interstices between the threads of a cloth which all textile fibres possess is less in artificial silk than in real silk, primarily because the filaments are thicker and of greater specific gravity The two silks again react differently towards different dyestuffs Thus, red ink immersion will stain natural silk almost permanently but not rayon which can be washed off. Finally, artificial silk like all vegetable fibres can be burnt with comparative ease emitting a distinctive acrid smell like that of burnt sugar, whereas true silk on incineration has, like wool, a fleshy smell of burnt hair or horn.

Properties of Silk

Real silk has, besides, certain special properties. It is a poor conductor of electricity—which fact has led to its use in the manufacture of electric cables. It can however be easily electrified by friction. Silk is also a poor conductor of heat which fact together with its agreeable lustre, softness and relative durability is availed of in the manufacture of garments. Silk, unless weighted while being manufactured, will not easily crease and is warm to the touch. It can also be dyed more easily than other fibres Finally, silk has a peculiar property, namely scroop—which means a rustle or crunching feeling, and this scroop becomes permanent when silk is immersed in a weak solution of acid.

Origination

The origin of the silk industry is acknowledged to be n China, the word 'silk' being itself derived probably from ts Chinese equivalent 'Tsi'. More than two thousand years before the Christian era, the Empress Si-sing-Chi of China, the venerated Lady of Siling, is credited with the encouragement of sericulture and with personal care of silk worms; she is even said to have invented the loom for weaving and is therefore worshipped as the Silk-worm Goddess. Under the patronage of royalty and nobility the silk industry throve there and many secrets were jealously guarded for several centuries. Not till 300 A.D. were Koreans sent from Japan to China to learn these secrets. They took back with them four Chinese girls who taught the court and the people the art of silk-making, for which effort a temple was erected in their honour in Settsu. The silk industry there quickly assumed national importance. Its spread into India* and the adjoining territories is also

* Some hold that the allusions to some sort of silk in the Rig-Veda and later Sanskrit works would point to the fact that silk must have been indigenous to India; but this may have been Tussur or or other wild silks. All evidence points to the introduction of the mulberry-feeding silk-worm into India from China towards the dawn of the Christian era. That is why it is referred to as the Indian Worm in later classical and Arabian literature.

romantic. A Chinese Princess is traditionally credited with the smuggling of moth, eggs and mulberry seeds in the lining of her head-dress. This is how sericulture is said to have been first established in the Ganges Valley, to spread from there southwards upto Mysore and westwards through Central Asia into Europe. It is on record that during the time of the East India Company, Indian silk played an important part in the European market. Aristotle however assigns the origin of silk to the Island of Cos where the first reeling and spinning of silk is also ascribed to a woman, a daughter of Plates.

Spread into Europe

Rome soon became the entrepôt for raw silk which was then worth its weight in gold. The Emperor Justinian reserved the monopoly of its trade and manufacture for himself and set up looms in his palace at Constantinople. When two Persian monks came to this city from China and imparted their knowledge of silk-worm rearing to the Emperor, they were induced to return to China to bring back the eggs of the silk moth which they did, concealed in a hollow cane. Thus was the begining laid for a regular silk industry in Europe. Byzantium fabrics became world famous and the conquering Saracens were responsible for the spread of the industry upto Italy where, in the middle ages, Milan, Venice and other towns became popular centres for the silk trade. Eggs were carried from Milan to France but no progress was made till premiums were paid for the cultivation of the mulbery plant in the seventeenth century. Early efforts for introduction into England met with little success but the immigration of Flemish weavers who fled from their country due to political reasons and of French artisans who fled later owing to religious troubles led to the establishment of silk-weaving colonies in England which are flourishing even today. The art of 'throwing'

But the art of weaving filmy muslins and gold brocades was already highly developed in India which perfected ornamental designs in silk brocades and these obtained world-wide reputation This art spread from India through Damascus to Constantinople and Tripoli.

is said to have been smuggled from Italy in 1718 by one Lombe who, disguised as a worker, obtained employment for the cultivation of the mulberry plant in one, of the Italian factories and copied the drawings of the machinery required.

Spread into America

Introduction into the New World was first attempted through Spain and later by King James I from England Though the first shipment of materials was wrecked at sea, Virginia received a second consignment in due course and sericulture was promoted there through bounties or enforced through statute. In spite of such encouragement, the silk industry failed to be profitable. In the year 1838 there was a speculative mania due to a report that the mulberry plant of the South Sea Islands was better suited for feeding silk-worms and these plants were in great demand, striplings being sold at as much as a dollar apiece. But the bubble burst in a year as the plant was found to be not extraordinary and the costly plantations had to be uprooted. The production of raw material has not, due mostly to the high cost of labour, made any tangible strides in America which, because of that fact possibly, takes first place in the production and consumption of artificial silk.

Varieties of Silk Moths

The mulberry silk moth is known as **Bombyx mori** and produces the best and the largest amount of raw silk. There are however at least six other species of **Bombyx** which feed on mulberry leaves and produce good silk. Some of them are **univoltine** that is produce one generation only in a year, like the large **Barapolo** of Bengal **(B. textor)** whose cocoons are soft and flossy. Others like the **Madrasi** worm **(B. Croesi)** and the **Desi** worm **(B. fortunatus)**, both of Bengal and the **Burmese** worm **(B. arracanensis)** lay eggs several times in a year and are **multivoltine.** All these feed on mulberry, the order of preference being white mulberry, then red and finally black. Worms feeding

on white mulberry yield the best cocoons. There are however wild silk-moths whose cocoons provide a large quantity of silk which is often called wild silk. Among these we may mention the **Tussur** moths which yield Tussoore silk: one variety is indigenous to India and feeds on the Bher and other trees; another (shantung) indigenous to China is found on oak and a third one is the **Eri** worm of Bengal, Assam and Burma which is fond of castor. The **Yama-mai** worm of Japan is an oak-feeder and for that reason attempts were made to propagate the species in Europe by smuggling eggs, but these were unsuccessful as oak leaves are not ready for feeding on that continent at the time when the larvae hatch out. There is also the **Atlas** moth common between India and Java with omnivorous larvae, the **Cynthia** moth of China, the newly-developed **Anaphe** of Africa which builds nests of cocoons with a strong outer covering and so many others from which wild silk is obtained. A comprehensive list will be given in the last chapter.

Varieties of Silk

Silk is either **filature** silk or spun silk. The former represents continuous filaments which are unwound or 'reeled', as the process is called, from the cocoons. It is therefore the best silk available. Spun silk on the other hand represents floss, damaged or unreelable cocoons, husks and other wastes, together sometimes with a certain admixture of wild silk, which are converted into yarn by the spun silk process in a manner similar to that employed for many other fibres. Such silk has not naturally the beauty, brilliance or body of reeled silk and is useful only for special fabrics, like linings, hosiery, sewing threads, webbing, plush, mufflers, etc. or for mixing with other fibres, e.g. for in-weaving of stripes, checks, etc.

Best Silks

The best raw silk is produced in Italy (**Piedmont**) or France (**Cevennes**) but the marketable output of such silk

is very limited. Failing these qualities, Japanese filature silk whose export represents 60 per cent of the world's total production in normal years can be regarded as superior to any other. It is "excellent in quality, clean, even, regular in count, good in colour, elastic, lustrous, fairly easy to degum, readily weighted and suitable for warp or weft in weaving as well as for knitting yarns" There is a Government Raw Silk Inspection Bureau there which tests and passes all silk intended for export. The best silk from China is equal to that of Japan but the quantity is limited, though in total exports China's share is 20 per cent of the world's output The market for China's best is at Shanghai while the inferior varieties are marketed at Canton. The former known as "Chinas" are pure white, while the latter "Cantons" are dirty and fluffy and lack the strength and firmness of the Chinas. The total production of India is reckoned at two million lbs. three-fourths of which comes from Mysore and the Kollegal district of Madras Our best is also derived from the mulberry-fed worm which is found from Bengal and Punjab upto Mysore. The Mysore silks with their light greenish tint, and fairly even and clean thread are regarded superior to the slightly yellowish Kashmirs which are in turn superior to the distinctly yellow and uneven Bengals Our wild silk Tussur is obtained from the Central Province, Bengal and Orissa. There is seri-culture in practically all the Continental Countries and in the Middle East.

Consumption

The largest consumption of raw silk is by the United States which has a large industry for producing finished goods for the home market and therefore imports only small quantities of fabricated articles. England on the contrary imports manufactured articles far in excess of raw silk, the manufactures from which are mainly exported. We import about half a billion rupees worth of silk goods of which about one fourth represent raw silk and waste, though we export about four million rupees worth of silk goods

including raw silk. In Europe, France is the chief centre of the silk trade which is located at Lyons: her imports and exports of raw silk and silk goods are indeed considerable. The Lyons Conditioning House which analyses and gives full information about silk and its hygroscopicity prior to its being worked at the factories is a model which many other countries have adopted and which India might copy. Among the other important countries are Italy with headquarters at Genoa and Germany with headquarters at Krefeld.

Production

Sericulture has always been a poor man's occupation being incidental to agriculture and can therefore be successfully pursued in densly populated rural areas where wages are low and holdings small. This is why it is not a profitable pursuit in America and other Countries, where the comparative yield from other competing crops or occupations is much greater. Other important factors governing sericulture are climate and soil, inasmuch as the silk worm can thrive only under certain conditions of temperature and humidity and in those places where its food can be grown economically. This is why the industry is confined to a belt of land encircling the world between 20° and 42° north latitude It was at one time thought that the religious prejudices of Hindus and Budhists would prove an obstacle to the production of raw silk in India—as the worms have to be killed before reeling; but the Indian Tariff Board has found that this is not exactly true, because the Budhists of Japan and China have no scruples and the Hindus of India who may have "appease their qualms by selling their cocoons before the life of the pupa is extinct" In any case, sericulture has always remained a cottage industry and, wherever attempts have been made to organise it as a large scale industry, they have not succeeded.

Progress of Rayon

As regards artificial silk, a comparative study of statistics of production and consumption for the last two decades

reveals an interesting story. In 1926, the total world production was only 235 million lbs. of which America and Japan had produced 74 and 6½ million lbs. respectively. The next three largest producers were Germany (30), Great Britain (38), and Italy (39). In another ten years the world production increased to 1027 million lbs. and Japan (326) beat the United States (312) into second place The production of Germany, Great Britain and Italy was also raised to 164, 119 and 106 million lbs. respectively But synthetic textiles, other than continuous filament rayon, came into vogue and the production of such staple fibre was recklessly expanded by Japan, Germany and Italy. America however continued to increase her rayon production by a hundred million lbs. annually, till in 1944 she ranked by far and large the greatest Rayon producer and consumer with a total production of about seven hundred million lbs.

Our Imports

India does not as yet produce rayon fibre or yarn. Our artificial silk mills engaged in weaving depend upon yarn imported mainly from Japan and Italy. These mills are of recent growth. Till 1926 our imports of rayon were under a million lbs., but in 1939-40 these had increased to over 37 million lbs. valued at some 26 million rupees Besides yarn, we import over 50 million yards of rayon piecegoods and a large quantity of mixed piecegoods. Converting this into yarn, we can take our annual consumption to be about 50 million lbs—which should in the opinion of experts support five or six rayon plants with a daily capacity of about 50 tons. The question of the availability of raw materials is not of unsurmountable difficulty as will be apparent after a perusal of the method of production in the fourth chapter.

Deniers

In international commerce both silk and artificial silk are governed by the Turin System of counting thickness which is expressed in Deniers. The count is given by the

weight in 0.05 gram of a thread of the particular silk which is 450 metres long. The fineness of all silk, unlike that of other textile fibres, is expressed by two numbers which represent the limits between which the average value must lie: these numbers usually differ by two units, though with some kinds of silk, the difference may be 4 or more. When we say 19/21D Organzine, we mean that 450 metres of this thread should weigh 20 x .05 = 1 gm and that it may be permitted to weigh either 19 x .05 or 21 x .05 gm. Natural silk is reeled as fine as 8-10 deniers or as coarse as 28-30 deniers and sometimes more.

CHAPTER II

SERICULTURE

The Silk-Worm

The so-called silk-worm is not a worm at all but the **caterpillar** or larva of the silk-moth. This moth belongs to a group of animals known as **insects** which have a special peculiarity in their life-history known as **metamorphosis***. Their eggs do not hatch directly into original insects but pass through two dissimilar stages, an active **larva** and a passive **pupa** or **chrysalis**, the latter in its dormant condition being gradually transformed into the final adult moth. In these stages of growth, the animals do not resemble their parents at all. Similar metamorphosis occurs in all moths which, along with butterflies, are grouped together in a comomn Order known as **Lepidoptera** to which the silk worm also belongs. Its family is **Bombycidæ** while the other silk-producing insects belong to different families. We are at present confining ourselves to the former.

The Moth

The real silk-moth is an inconspicuous insect of an ashy white colour, hardly half an inch long, with short and weak wings. The female moth is usually longer and stouter. Neither has any nutritional organs and each seems to live only for the sole purpose of propagating the species. The male's life ends as soon as he has fertilised a female and the female dies as soon as she lays eggs. She lays about 250 eggs in her life-time In some species, especially the European ones, reproduction takes place once a

* For further information on this subject, the reader may consult with advantage the book on insects published in this Series.

year, in Japan which produces the largest quantity of silk, the race is bivoltine, breeding twice a year; while in India and China reproduction is almost continuous throughout the year. It has been said that the quality of silk depends upon the number of hatchings, being in inverse ratio thereto.

Life History

The eggs of the silk-moth, known as silk-seed (or graine) are bluish violet granules later becoming dark grey and resemble poppy seeds They weigh about 100 to a grain They hatch, under proper conditions and within about a month, into caterpillars or larvae. These, the so-called silk-worms, are of an ashy grey or cream colour, have no hairs and have four pairs of legs on the hind segments There is also a horn-like protruberance towards the tale The mouth parts are adapted for biting and the *worm is a voracious eater, its size increasing many times* over till it reaches an ultimate length of between 3 to 3½ inches When it reaches maturity, it develops silk-glands along the sides of the body which open out on the under lip through a common orifice known as a spinneret or seripositor Through this orifice is exuded a clear viscous fluid which solidifies as silk on exposure to the air. The exudation is in the form of a continuous thread over 3,000 yards long (of which about 800 yards are reelable) which is utilised by the larva in spinning a protective shell or cocoon round itself, by moving its head in a regular order continuously for about three days and laying the thread over itself in the form of figure 8's. The cocoons are white or yellow in colour, oviform in shape and often with a constriction in the middle. They are about half to one inch in diameter and half as much again long. At first they are soft but soon become hard and parchment-like. Inside the cocoons the larvae pupate, that is, remain dormant as pupae or chrysalids, for about 2 to 3 weeks, during which period they undergo tremendous transformations in order to become full-fledged moths. These bite their way through

the cocoons and escape. The males and females pair off almost immediately and start repeating their life-cycle.

Mulberry Trees

Advantage is taken by man of these facts of Nature to produce silk for himself under artificial conditions. The moths are domesticated and trained to form cocoons which are secured before they are pierced or damaged, the whole art being known as **sericulture.** The first essential requisite in this art is a stock of mulberry trees whose leaves form the chief food of the silk-worms. The white fruited mulberry **(Morus alba)** which grows as a tree is chiefly used in Kashmir and the Punjab (as in Europe) where nurseries are maintained for producing seedlings from selected trees and distributing among the cultivators. Where the black-fruited mulberries **(M. nigra)** grow, their leaves are used only for worms of mature age. In Mysore, Bengal and other parts of India the mulberry is of a different variety **(M. Indica)** and grows as a bush, though efforts are being made to cultivate it as a tree The Mysore State has established farms all over for purposes of conducting experiments in the cultivation of the mulberry. The Madras Government runs a school of sericulture at Berhampur in the Ganjam District, where too experiments are regularly conducted and where complete training in all branches of sericulture through uptodate equipment is imparted to students over a course of about 2½ years.

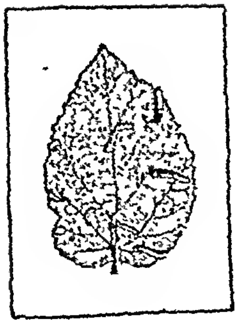
Egg-production

Wherever sericulture is practised, the production of eggs has become a specialised branch of the industry: for, it is not only necessary to maintain a good strain of silk-worms by selective breeding but also to safeguard against the propagation of hereditary diseases by a microscopical examination of female moths after she has laid eggs and destruction of any eggs that are found to be diseased. This is why egg-production is often confined to selected rearers or to Government-controlled 'grainages'. There are special

seed-houses in Kashmir, Punjab, Mysore and elsewhere. Kashmir, where the industry is a state monopoly, has no indigenous silk-worm now, as that state used to import most of the seed required from France, Italy and other countries and produces seed of a cross-bred type. Mysore too has imported small quantities from Japan and China and issues cross-bred disease-free seeds. The seeds are kept in hibernation at a sufficiently low temperature till the hatching period arrives. This is usually about the time when mulberry trees begin to break into leaf. Where the climate is not uniformly hot, incubation of eggs by the application of heat becomes necessary. Simple incubators are used so that the hatching becomes regular and simultaneous, thus making the feeding more economical. The seed which is distributed in perforated boxes is spread out on trays and placed in the incubators whose temperature is originally about 65° F. and is raised gradually by 2° to 77° when hatching takes place.

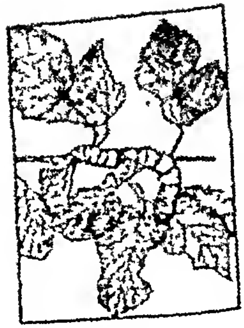
Rearing

The trays are then withdrawn from the incubators, and gauze or perforated paper over which are spread finely chopped and tender mulberry leaves are covered over the minute worms which now start wriggling through the holes and begin feeding. Or else, the worms are brushed out from the trays by shaking or stroking with feathers. This is done either in the rearers' own houses or in special rearing houses where there are frame-works for holding the trays What is required is strict hygiene, an equable temperature, good ventilation and freedom from damp, draughts and heat. In India, the trays are circular and made from bamboo, arranged on stands. The worms increase in size wih astonishing rapidity and display a growing voracity. After three or four days they are able to consume whole young leaves and are given more and more space on the stands so as not to be suffocated through over-crowding. The following diagram shows silk-worms, six and ten days old, feeding on a mulberry-leaf.



Feeding

The growing worms continue to feed for about 42 days, during this period they have four periods of sleep, lasting about 24 hours each, on the sixth, twelfth, eighteenth and twenty-sixth day after hatching. On each of these occasions, their skins crack and are shed out or moulted on awakening. In the first two periods the worms are very susceptible to diseases If all the worms have been hatched out at the same time, they all go to sleep simultaneously which is certainly conevient for the rearer. As the worms grow older they feed on more mature leaves which should however be green and not much wilted. The leaves are best collected over-night though in some places branches are hacked out and laid on the stands. After the fourth moult, the worms start on their grand final feast lasting for about ten days when they consume about twenty times their own weight of leaves. It has been calculated that one oz. of seed produces between 30 to 35,000 silk-worms which require about one ton of leaves for a complete rearing, more than half of which is consumed after the last moult. The tiny black worm on hatching, when it becomes a full-fledged whitish worm, increases in weight by about ten thousand times to ten grains and in length by about thirty-six times to over three inches. The excreta, unconsumed leaves, etc. must be cleaned out from the stands periodically. The following diagram shows a full-grown silk-worm.



Cocoon-spinning

When the silk-worms are fully ripe, they are ready to spin cocoons. The signs of ripeness are a shrinkage in length, yellowness of colour, roundness of shape, a sluggish appetite and softer excreta. They now begin to raise the forepart of the body waving it from side to side. The silk glands in the body become greatly enlarged and the worms begin to discharge silk. It is at this stage that provision has to be made for cocoonages or structures on which they can rest and spin cocoons. In many countries branched twigs and shrubs are placed vertically athwart the stands In Kashmir, branches of mulberry itself are used In the rest of India, the cocoonage is a rectangular bamboo mat fitted with a spiral tape of bamboo, which is known as a 'Chandrika'. If the worms are not fully ripe, they are likely to fall down and spoil other cocoons. so individual worms are picked up as they are ripe and deposited on the cocoonage. There should be sufficient space between the worms and no over-crowding; otherwise, two worms will spin a joint cocoon which has no reeling value The worms first spin a sort of hammock by discharging from their spinnerets filaments of silk from one side to the other and, lying on this bed, they spin a similar layer above themselves These two layers are then wound round by a continuous filament in the form of a series of 8's The time taken for spinning the cocoons is usually a day, and in one more day the larval skin is cast, after about

ır more days, the cocoons are sufficiently set and can . gathered. The gathering cannot be delayed for more an eight days, as otherwise the pupae inside the cocoons ould complete their transformations and emerge from ıe cocoons as moths by cutting through the silk-fibres 'hich would thus be useless for reeling.

Mating

Some selected cocoons are indeed preserved intact for ıe formation of silk-moths for breeding and producing ggs These are threaded together into long ropes and sus- ›ended from the ceiling to within a foot of the floor. Soon he moths emerge and mating takes place. The males fter two or three matings are destroyed. The females are ›laced in small linen bags about 2 inches square. The bags ıre tied up and strung together to be suspended from the ːeiling. The females lay their eggs inside the bags and die. The bags are emptied and the seeds are washed in order o free them from the remains of the dead females. A ew sample seeds are crushed and examined where possible under the microscope to see whether they are free from diseases If they are not, the bags and their contents are burnt. This is more necessary in the case of **'cellular seed'** intended for propagation in the next season as opposed to **'industrial seed'** intended for silk-reeling where a margin of 5 per cent diseased seed is permitted. In many places, it is customary to put the female moths on special trays where they are allowed to lay between 20 to 60 eggs which are kept separate for breeding as moths, they are then taken to other trays where they lay over 200 eggs which are ear-marked for silk-making. The industrial seed is packed in small gauze bags in weights of ¼, ½ or 1 oz. which are placed in perforated boxes and issued to rearers. Cellular seed is only issued to selected rearers.

Stifling of Cocoons

The rearers either sell the cocoons green, that is before the pupae inside are killed, or dry, that is after

stifling the pupae. The cocoons are often sorted into grades when they fetch better prices. The method adopted for killing the pupae is suffocation. Ordinarily, the villagers suffocate by exposing the cocoons to the heat of the sun, but this is not a good method, as the gum in the thread becomes hardened making unwinding difficult and the colour of the silk too fades somewhat. The best method is of suffocation through steam. Bamboo baskets holding about 25 lbs. of cocoons are held for about 40 minutes over cauldrons of boiling water. In the best regulated rearing stations, airtight chambers are constructed over cauldrons of water placed on fire and steam percolates through the bottoms of the drawers, thus stifling the cocoons in eight or ten minutes. At Bangalore they are kept in such a chamber for about half an hour. The cocoons are then spread out on canvas beds and allowed to dry by being frequently turned, when the dead pupae inside shrivel up without becoming putrid or damaging the silk. If the cocoons are not properly treated, the pupae may revive and cut through as moths. The best method of suffocation is through hot air as practised in France. There, air is fanned into the dryers (Séchoirs) through steam-coiled chambers raising the temperature to about 200° F., so that in about 12 hours not merely are the pupae suffocated but the cocoons are rendered completely dry. Dried cocoons can be stored without damage for months. The reeling of cocoons by which is meant the unwinding of the silk filament is done at what are known as the filatures and will be described in the next chapter.

Kinds of Cocoons

The average yield of cocoons in India is not as great as in continental countries. Whereas France reports an yield of about 100 lbs. of cocoons from one ounce of seed and Italy 120 lbs., our highest yield is in Jammu (86 lbs.), next comes Kashmir (84), then Madras (60), Mysore (50), Bengal (48) and Punjab (20). The last figure is not regarded as quite accurate. The whole cocoon with its en-

ɜed pupa weighs from 15 grains for the smaller races to ›ut 50 grains for the larger ones. Cocoons are graded international commerce into several classes which have en given Italian names. The best cocoons, elliptical in ape and slightly constricted in the middle, are known as ›ale from which the cleanest and best-shaped ones are ngled out as **Classica.** If the cocoons are malformed or 'eak, they are Realino. Where the larvæ have died inside ıē cocoons leaving dark spots, they are **Morti** and where ıe worms have not developed properly owing to unsuit-.ble feeding and the cocoons are therefore loose in exture, they are **Cartella.** All these can be worked up by eeling. There are however cocoons which cannot be reeled ə.g. **Doppi** or double cocoons, **Bucata** where the moths have cut through and emerged and **Bosco** which comprise all soiled, mis-shaped or transparent cocoons.

Tussah Worms

Among other silk producing worms of importance, pride of place, so far as we are concerned, must be given to **Tussah** or **Tussur (Tassar)** from which the material known as Tussoore is woven. This worm abounds in the territory bounded by the three rivers, Ganges, Godavari and Nerbuda, though it is found much further north and as far south as Mysore as well as in China. The worm feeds on a variety of jungle trees especially the leaves of Asan, Sal and Bher*. Cocoons are brought from jungles and retained till the moths which are large and fine-looking emerge. As the moths do not pair in captivity, the males are allowed to fly away and the females are kept with an attached thread. Other males come for pairing and eggs are laid on the next day after which the females die. The eggs are taken to the appropriate food trees in about a week for hatching, as tussah worms unlike silk-worms cannot be trained to feed in rearing houses. The worms are transferred from tree to tree when the leaf-stock gets exhausted. They spin their cocoons after about

* *Terminalia tomentosa*, *Shorea robusta*, and *Ziziphus jujuba* respectively.

eight weeks As these cocoons which are large and brownish in colour get water-logged through immersion, they are merely wetted before reeling which is usually done by women as a cottage industry. The silk is uneven and stiff with a glossy lustre. Three crops of tussah cocoons can be taken in one year. Central Province alone claims to produce 2,000 maunds of Tussore silk per year.

Eri Worms

The Eri silk-worm which is found mainly in Assam and Bengal thrives on the leaves of the Castor Oil plant. Unlike the tussah worm, it can be domesticated and the rearing is always done at home It yields four crops in a year. The cocoons are soft and tangled with a delicate filament so that reeling is impossible and the silk has to be spun into yarn. Thus, stifling of the larvae inside the cocoons becomes superfluous and the moths are therefore allowed to emerge and fly away. In many places the worms are allowed to live wild and to find their own food. Attempts have been made from time to time to introduce these worms in other parts of India. Eri Silk is ct a very poor grade and fetches a very low price.

Muga Worms

There is another silk worm in Assam and adjoining localities known as Muga or Moonga whose silk is about five times as valuable as that of Eri. The worm is partly domesticated as it must be fed outside on the trees (Sum or Sualu trees preferably) though it will hatch from the eggs and spin cocoons under captivity While feeding, the worms have to be protected from bats and birds The pupae are suffocated inside the cocoons through heat as in the case of silk-worms as Muga silk can be easily reeled. The Muga moths are bivoltine.

Other Worms

Among other silk worms which are listed comprehensively in the last chapter we may refer to the atlas which

* *Machilus odoratissima* and *Tetranthera monopetala* respectively.

produces **Fogara Silk** in Eastern India. The cocoons are long and light brown, open at both ends from which the moths can easily emerge but the silk cannot be reeled and must be spun. The **Yama-mai** of Japan which produces silk more like that of the mulberry-feeding worm and whose egg-export was forbidden for a long time produces cocoons of medium size and reelable silk of a pale green colour. There are other moths which yield silk but are not of any commercial importance. We may here, out of curiosity, refer to **'Mussel Silk'** produced by a kind of **shell-fish*** inhabiting the Mediterranean, and anchoring itself to the sea-floor by means of silky threads. These threads are brought upto the surface near Sicily through wooden poles and yield a soft elastic silk after being washed, dried and combed.

* *Pinna nobilis.*

CHAPTER III

SILK MANUFACTURE

Essence of Reeling

In the last chapter we have described the formation of cocoons and we have seen how some are reelable and others not. The latter are sorted out and kept along with silk-waste for producing spun silk which we shall describe presently. All cocoons have an outer covering of loose fibre known as 'floss' enveloping a continuous filament of silk which is wound round an inner parchment-like shell enclosing the pupa The art of reeling consists in separating the continuous filament from the other parts of the cocoon and in combining it with other filaments so as to produce a thread of desired denier or thickness and thereafter in winding this conjoint thread on to a reel. Reeling is done either manually or by machinery and in India we have Charkas working individually as a cottage industry as well as filatures with power-driven machinery. About 80 per cent of the silk produced in India is reeled on Charkas In either case, the pupae inside the cocoons must first be scotched if this has not already been done before the latter are received by the reelers.

Preliminary Processes

The process of reeling commences with a preliminary 'Cooking'. The cocoons are first soaked in hot water and brushed so that the outer fibres become loosened and the floss can be removed This, in the primitive methods connected with the Charkas, is all done in the same basin in which too the cocoons are allowed to remain for the final reeling, with the result that the thread that is produced is not clean, compact or uniform and the gum is not thoroughly extracted. At the filatures on the other hand

where brushing is automatic through a brass broom working automatically in a circular fashion, the preliminary washing and scouring are done by a separate worker who catches up the cleaned cocoons from the basin (where water is kept upto boiling point) by means of a strainer and passes them over to the reeler who empties them into his own basin contatining water kept at a certain level automatically and heated by a steam coil upto about 180° F. This leaves very little gum and waste attached to the thread as will be evident from the **rendita**, meaning the quantity of cocoons required to produce one pound of raw silk In Mysore this quantity is 19 lbs., in Bangalore and Kollegal 17½ to 15¼ lbs., and for ordinary charkas 13 lbs, the reason being that the greater the quantity of gum and waste remaining on the thread, the greater is the weight of the silk and the less therefore will be the quantity of cocoons required to produce a given weight of silk.

Reeling Proper

The reeler proper now takes up the fibre ends of as many cocoons issued to him as are necessary to produce the required denier, passes them through an 'eye' so as to consolidate them, sees that it is twisted either against itself or against another thread and finally winds the consolidated thread on to the reel In Mysore charkas, the ends are passed through holes in strips of bamboo, whereas in Bengal iron plates with or without porcelain buttons are used. In filature practice, the combined thread is passed through an apparatus about 2 inches above the water level, upwards about 18 inches round a tiny glass conducting reel, then downwards round a similar glass reel and upwards again until the thread crosses itself. Here it is twisted round itself many times and is then taken through a glass hook over the reeler's head to the reel on which the skein is to be wound. The process is repeated till the four, six or eight threads, each consisting of the threads say of six cocoons, are attached to the reels which are set revolving by a control lever and thus pull the threads. If eight skeins are being reeled, their 48 cocoons all begin to turn

about in the water as they unwind themselves The twist imparted during the reeling helps to round up, smoothen and condense the six separate filaments into one strand agglutinated together as a compact single fibre of silk and to expel from it all moisture in the form of a spray. The following illustration showing a Japanese reeling girl will help to explain the process above described

The Silk Filament

It is the reeler's business to keep a close watch on the cocoons in the basin and as soon as the filament from one cocoon breaks or is completely unreeled another filament from spare cocoons kept near him is joined in its place The silk filament of the cocoon is a somewhat flattened combination of twin filaments placed side by side, being on an average $\frac{1}{1200}$ inch in thickness It becomes thinner and thinner as it unwinds itself. If in the early stages of unwinding it is of three deniers thickness, it is

2½ deniers in the middle and 2 deniers towards the end, so that in order to arrive at a size of 13-15 deniers it is required to reel a thread of two new, two half-reeled and two nearly finished cocoons. The filaments of Mysore cocoons are much thinner, between 1½ to 2½ deniers and therefore more cocoons will be required to arrive at silk of 13-15 deniers. Occasional tests are carried out to see that the size is properly maintained. A final examination for picking off any pin-head knobs on the thread or for removing coarse pieces and substituting clean thread in their place takes place before the skeins are twisted up and packed into bales.

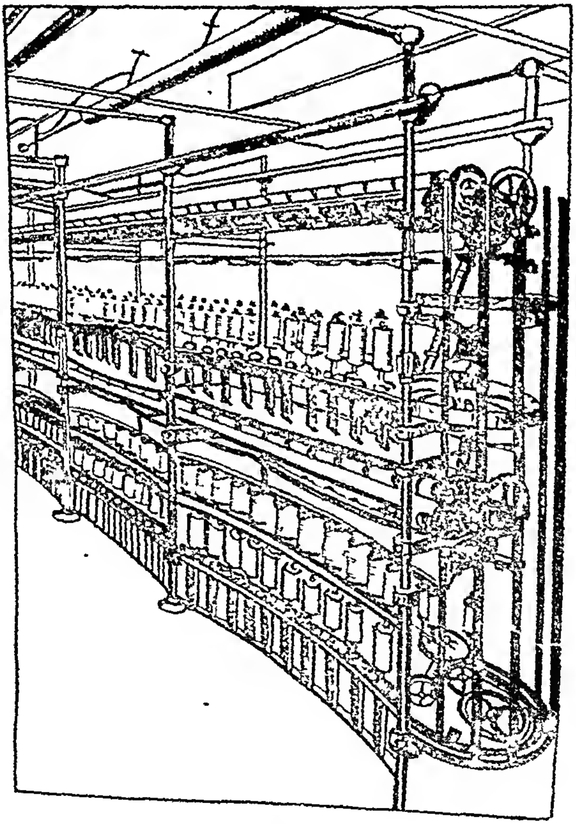
Re-reeling

Where silk is reeled on charakas, it is neither even nor clean and therefore cannot be used by weavers without subjecting it to a further process known as **re-reeling.** The commonest Chinese raw silk **Tsatlee,** a product of the household industry, is a very primitive kind of reel showing inconstancy in size and therefore, like our domestic reels, requiring re-reeling. Re-reeling is a common feature of the Chinese and Japanese silk industry, while in India it is still in its infancy. In Mysore some of the silk-centres attend to it but in Bengal it is usually done by women in the weaver's house. They simply wind the silk from the skein as received from the reeler on to a fresh reel attending to manifst blemishes or mending breaks and removing dirt at the same time.

Throwing

As raw silk is too fine and delicate for use either as warp or weft, it undergoes a series of operations known as Throwing. This in the west is done in Throwing mills where the first operation, after splitting to reduce the denier and washing to remove the gum if necessary, is to put the hanks on light reels called Swifts and to wind thence on to **bobbins** which are taken to a spinning frame. There the single strands receive their first twist. Then follows the operation of cleaning in which the silk is reeled from one bobbin to another, passing through a slit wide enough to pass only the filament but not thick lumps or

nibs. These latter are removed and the filament is now doubled, that is two or more filaments are wound together side by side on the same reel so that they can be twisted or thrown into one yarn. This is done on a doubling frame which stops automatically when a thread fails. The final operation is spinning, or throwing proper, which is done on a frame with upright spindles and flyers, the yarn as it is twisted being drawn forward through guides and wound on revolving bobbins with a reciprocating motion. From these bobbins the silk is reeled into hanks of required lengths. The following diagram shows a silk throwing machine:—



In India we have very few throwing mills and the weavers either get the various processes performed crudely by hand or use imported thrown silk, as hand twisted yarn canot compare in strength, lustre etc., to really thrown silk. Thrown silk falls usually into three classes, 'Singles' being single strands of twisted silk made up of the filaments of 8 to 10 cocoons, **Tram** or thread used for the weft which consists of 2 or 3 strands not twisted before doubling and only lightly spun, and **Organzine** or warp thread made from two twisted strands spun in a direction contrary to that of their original twist as it must possess great breaking strength.

Conditioning

There are certain other processes through which raw silk is sometimes passed before it is ready for the weaver. It is for instance **conditioned** at the Conditioning Houses, by heating for four hours and thus expelling its natural moisture and then adding 11 per cent of its weight of pure water. The silk is also **scoured** by boiling in a solution of 30 per cent of its own weigth of neutral soap dissolved in sufficient water to give a one per cent solution. This boils off the gum or albuminous matter and thus restores lustre as well as makes the silk a brilliant pearly white. For certain classes of goods the silk is **weighted**, that is made to absorb various metallic salts and organic substances. As by scouring raw silk loses about one quarter of its weight, weighting is said to be '**to par**' if that much quantity is restored and 'above par' if more Weighting never exceeds 50 per cent above par. Silk is also dyed in some cases before being woven; it responds to acid, basic or direct cotton dyes, and even to vat or mordant dyes except that tussur and other silks which are yellow cannot be dyed with light or brilliant colours.

Spun Silk

Apart from reeled silk there is what is known as spun silk which is obtained by spinning silk waste (chasam). It

has been stated that the process of spinning silk was much older than that of reeling, as the art of unwinding was not discovered till much later. The Chinese were the first to spin silk Today only unreelable silk or what is known as silk waste is spun. By waste is not meant old or second-hand silk but the bye-product of raw silk. This consists of the outside layer or floss of cocoons, the inner envelope or husk in which is enclosed the pupa, double cocoons, cocoons through which moths have pierced in order to escape, spoiled cocoons, reeler's waste, waste produced in throwing etc. Such waste was practically thrown away as useless till machinery was invented for spinning it. Though Eri silk is spun in India, silk waste is seldom spun here except in a few instances where it is hand-combed and spun on the wheel. The two silk mills which had facilities for spinning silk are not operating now and except for a small quantity used by a few cotton mills for mixing, the bulk of our waste which is of a very inferior quality is exported to foreign countries

Schapping

Spun silk is either schappe yarn or discharged yarn. The former is the French or Continental method by which the waste is piled up in large kilns and covered with hot water; it is then hermetically closed and left for a few hours for the gum to ferment and loosen. When thoroughly loosened, the silk is taken out and soaked in vats of hot water for a few hours It is then taken to the washing machine where the gum is washed away. The silk is finally heated in hydro-extractors and dried in rooms kept warm by steam-pipes Schapping leaves about 8 to 10 per cent of gum in the yarn which is of distinct advantage where very short fibres are to be spun Schappe yarn is necessary in certain industries e.g., for velvet manufacture As schapping produces very offensive smells through fermentation, it cannot be practised in or near inhabited places and the degumming plants of France are therefore located in the hills near streams of fresh water.

Discharging

Discharged yarn on the other hand produced in England from silk waste, being entirely free from gum, has a better brilliance and purity of colour. The waste, after extraneous matter has been abstracted, is put in strong open-meshed cotton bags holding from 1 to 5 lbs. About 100 lbs. weight of bags is then put in large wooden tubs and covered with boiling water containing 12 to 20 lbs. of dissolved curd soap. The silk is boiled in it for about 2 hours and then hydro-extracted of the dirty gummy solution. It is again put in another tub of soapy liquor and boiled and again hydro-extracted. It is then taken to a stove and dried. Thus all the gum is discharged. Cocoons on being degummed are taken to cocoon beaters where the fibres become loosened and dirt, dust and pupa residues fall off. Open wastes are degummed by fermentation in maceration pits containing a dilute soda solution heated by steam pipes. After about eight days the fermented waste is washed, first in hot then in cold water, centrifuged, dried and sprinkled with soap solution.

Spinning Proper

The next step for either schappe or discharged fibres is to open out the fibres. The knotted tangled mass passes over several drums fitted with steel teeth so that it is loosened and unravelled. It is then **'combed'** so that the separated fibres lie parallel to each other. After thorough combing the fibres are formed into a ribbon or sliver and then stretched or drawn by means of two cylinders, one rotating more rapidly than the other. The sliver is now slightly twisted to form the soft filmy **roving** which is taken directly to the spinning machine. This is either a **ring spindle machine** or a **self-acting mule.** In effect the spinning of silk waste runs on lines parallel to cotton spinning though the machinery used for the latter is not suitable for it and must be specially prepared. As single spun silk yarn is seldom used by weavers, it is usually doubled and twisted to give two-fold or three-fold yarn The yarn is finally

cleaned in the same manner as organzine yarn. Baurette yarn is obtained by spinning the waste which remains adhering to the machines after combing and is spun in a similar way to carded wool. It is coarse and uneven and very inferior silk.

Uses of Spun Silk

It will be apparent that spun silk is pure silk as much as throwers' silk It is also distinguished for its strength and lustre. Spun silks are used largely for silk linings, hosieries, sewing threads, elastic webbing, lace, trimmings plush, velvets and many other purposes such as mufflers, handkerchiefs, dress goods and blouse silks, also for mixing with other fibres in the form of stripes, in the weaving of various fabrics or for producing mixed goods. It is imported by India for manufacturing various classes of goods. Spun silk goods imported by India from Japan and China go under the names of Fuji or Boseki.

CHAPTER IV

ARTIFICIAL SILK

Definition

The name 'artificial silk' is generally used to denote a fibre similar in lustre, handle and appearance to natural silk but produced artificially. The name is somewhat misleading as there is nothing really in common between the two silks. In fact, the Sericultural Association of France has long since urged that the name should be changed and the Silk Association of America actually filed a suit in 1913, though without success, against the using of this name. This controversy is on a par with the statutory prohibition of the words 'vegetable ghee' to denote a similar artificial product. Though the word silk in artificial silk does not mislead to such an extent, the name Rayon has since been introduced and universally adopted.

Historical

Various attempts have been made in the past to invent a substitute for the flossy and lustrous fibre of natural silk. About 200 years ago, a French Scientist Reaumur suggested that as silk was nothing else but hardened varnish, it should not be impossible to draw out certain varnishes into spinnable threads resembling silk. These are his words: "Since silk is formed from a continuous gelatinous liquid, other natural substances of a similar kind ought to give silk or something resembling it". The year 1885 really marks the dawn of the rayon industry. It was Swan who obtained his famous patent in that year for his discovery of the process of manufacturing a filament from cellulose which is the chief component of cotton and other vegetable fibres by converting it into a viscous

solution and squirting it through a hole in a plate He and his successors were however more interested in producing by this method suitable carbon filaments for incandescent lamps than in developing a new textile fibre The great Scientist Pasteur who was entrusted by the French Government to study the then rapidly developing diseases of silk-worm, and to suggest suitable remedies therefor had under him a student named Count Henri de Chardonnet. it was Pasteur's inspiration that enthused the latter and enabled him to treat cotton with a mixture of sulphuric and nitric acids so as to form **gun cotton** and then to dissolve it in a mixture of alcohol and ether, so that the solution could be produced into threads by forcing it through glass jets. His original idea was to use the fibres of mulberry leaves on which the silk worms feed and which have a chemical composition allied to silk, as his raw material but he soon switched over to cotton and other vegetable fibres. Although his patent was two years earlier, it was in 1885 that the exploitation of the patent on a manufacturing scale began. His rayon fibres and garments exhibited at the Paris Exhibition were much admired Though the names of many other scientists are connected with the development of the artificial silk industry, we can but name only two, Cross and Bevan, Englishmen, who not merely introduced wood fibre as an ideal raw material but also devised the first practicable manufacturing process of what is known as **Acetate Silk.**

Raw Materials

There are at present four methods of making artificial silk: the original **Chardonnet or Cellulose Nitrate** process, the **Cuprammonium** process, the **Viscose** and the **Cellulose Acetate.** The basis for manufacture for all these is cellulose obtained either from cotton linters or waste or from wood. Cotton linters are the short seed hairs or staples of the ripe cotton seeds which are separated from the longer ones in ginning as being worthless for spinning. They represent about one-fifteenth of the total output of raw cotton. The wood whose fibres are used must be soft

and seasoned like that of spruce, fir and pine obtained chiefly from Canada, Sweden, Norway and Finland. Though we have similar timber in Kashmir and the Himalayas, there is yet no exploitation of their fibres for manufacturing either rayon or paper Attempts have been made to produce artificial silk from casein, gelatine, albumen and other proteins by treatment with ammonia and other re-agents but the products are not of much commercial importance. Inventors have also been busy in producing artificial silk from silk waste but the raw material is expensive and the resulting 'half-silk' is poorer in quality than spun silk in the manufacture of which these wastes can be and are satisfactorily utilised.

Main Principles

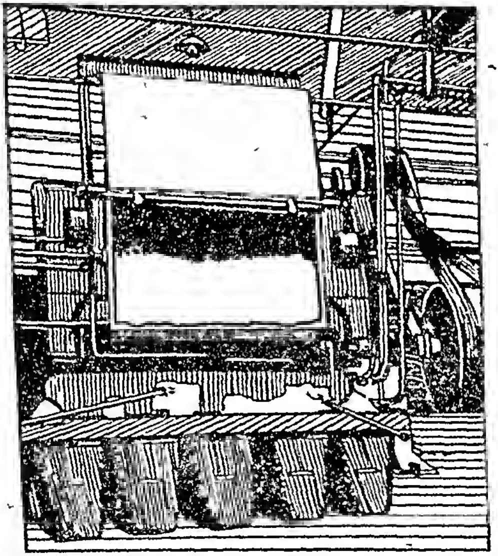
Raw cotton is no doubt easier to convert into cellulose and the thread obtained is purer, stronger and superior but the cost is comparatively greater than for conversion of wood into degummed pulp. Whether it is cotton or wood, the main principle of rayon manufacture lies in their formation into cellulose in the shape of thin sheets and in the dissolution of these sheets through chemicals into a viscous spinning solution which can be converted into fine filaments by forcing it through minute orifices in spinnerets: these viscous filaments are finally set or solidified either by evaporating away the liquid with a current of dry air **(dry process)** or by making use of a coagulating or setting bath into which the filaments exuding from the spinnerets can solidify and any chemicals holding the cellulose become separated **(wet process)**. The dry process is similar in principle to the spinning processes of silk worms and spiders whose silken filaments also solidify on extrusion and exposure to air. In the following diagram, the first figure represents short-fibred fuzzy cotton linters, the second thin chips of spruce produced by splitting flat slabs about an inch thick, and the last either material in the form of corrugated sheets of purified pulp resembling thick blotting paper:—

Viscose Rayon

We shall first describe the processes connected with the manufacture of Viscose Rayon as the great bulk of artificial silk, about 80 per cent, is now made by this process. One of the greatest advantages for this kind of Rayon is that its raw material is wood pulp which is comparatively cheaper than cotton. The conversion of wood into cellulose sheets and the manufacture of silk from these sheets are two entirely different processes, there being separate factories for each at different centres. In the cellulose factories, the wood is debarked by machinery and freed from non-cellulose matter such as lignin, resin and gums and is converted into **sulphite pulp*** which is pressed into somewhat corrugated sheets resembling very brittle cardboard as shown in the illustration. As soon as these sheets arrive at the rayon works they are conditioned, that is to say, they are dried so that they would contain a uniform and definite amount of moisture, usually about six per cent. The sheets are cut if necessary by means of a guillotine to sizes convenient for the next operation of steeping. This is done usually in steeping presses unless torn cellulose is used when iron steeping machines are employed. The steeping presses are hydraulic and the conditioned sheets are placed in them vertically between pairs of perforated plates in a solution of about 17½ per cent caustic soda The steeping or mercerising takes place for about 2 to 2½ hours after which the hydraulic ram is moved to press out

*For a description of sulphite and other varieties of wood pulp, the reader may consult the book on Paper published in this Series

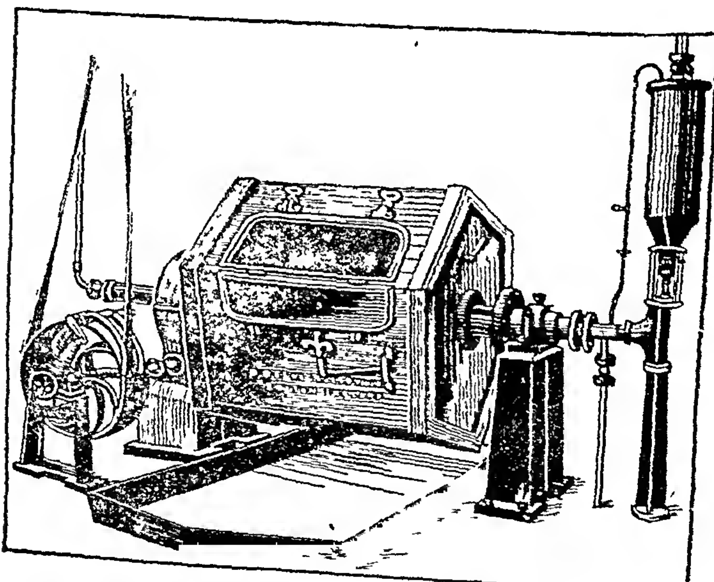
a certain portion of the caustic soda solution which is recovered for purification and re-use. The ram is again moved inward so that more solution is drained off. In some cases steeping and pressing are done as separate operations. The pressed Alkali cellulose sheets are now transferred to machines known as "pfleiderers", possessing toothed arms turning at different speeds where they are disintegrated or kneaded into small light particles which appear somewhat like white bread crumbs. These machines are usually situated on a lower floor so that the sheets can be delivered into them directly through chutes. The crumbs are discharged from them into trays from which they are raked into wedge-shaped tins, as shown below:—



Formation of Xanthate

These tins are now lidded and run to an underground room, the Mercerising Cellar, whose walls and ceiling are insulated and where the temperature is controlled to about 72°F. The crumbs are kept here for 2 or 3 days so as to permit the mercerising to be completed This maturing

process has to be so regulated that weak filaments may not result ultimately through over-maturing or the subsequent spinning may not be rendered difficult through insufficient maturing. The matured crumbs are now weighed and transferred to churns which have a smooth inner surface and which are revolved slowly (about one revolution per minute). A measured quantity of carbon-bisulphide is introduced into it by a spray pipe running axially across the churn from a measuring vessel situated at the side as shown in the illustration below. The churning occupies about 2½ hours during which period the carbon bisulphide combines with the alkali cellulose and converts the creamy white crumbly material to a brownish soluble gelatinous mass known as **Cellulose Xanthate** with an increase in weight of about ten per cent. The excess carbon bisulphide is extracted from the churns by suction and the Xanthate is emptied on to trays as shown below.—



The Xanthate is now taken to mixing machines which have grinders and suction pumps fitted so as to ensure thorough mixing. They have also cooling jackets which help to control the temperature. Sufficient caustic soda is introduced while the lumps and undissolved particles are being broken up inside and if the production of delustred yarn is the final goal, suitable compounds are also added at this stage. The process lasts between 2½ to 3 hours and the solid cellulose is now converted into liquid viscose which is ten times heavier than the original product and does not contain more than 7 to 8 per cent of pure cellulose. This viscose resembles syrup and is golden brown in colour but is immature and contains fine impurities which must be removed. It is therefore passed through a process of filtering and ripening. For this purpose the viscose is pumped into maturing tanks situated in ripening cellars or caves where it is kept for sometime. It is then forced through a filter press and passed through several thicknesses of finely woven cloth and through thick pads of wadding into a second series of storage tanks and again filtered and again stored, till after the final filtration it is forced into large spinning vessels or containers and kept there under vacuum for about a day, so that it becomes freed from air bubbles which would otherwise interfere with the formation of continuous filaments The whole ripening process takes anything upto a week though there is a tendency to reduce or even dispense with it in order to shorten the manufacturing process. The series of processes leading to the formation of spinnable viscose requires experienced scientific control at every step in order to produce a final product of uniform quality.

Wet Spinning

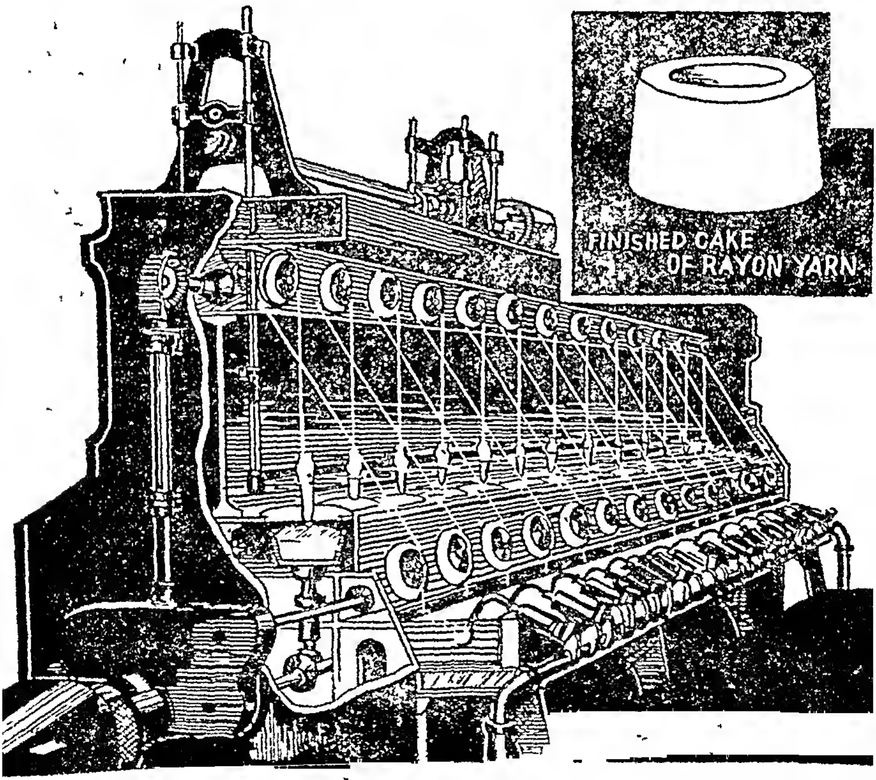
Viscose rayon is produced by the wet spinning process. This is easily explained. If a little viscose is poured into a glass of water, it will become thinner; if, instead, it is poured into a glass of dilute acid, it will coagulate and be-

come solid. This is because the viscose is composed of vast numbers of cellulose molecules suspended in an alkaline solution and the alkali helps to keep the molecules apart, but the moment the alkali is removed or neutralised by the acid, the molecules rush together and cling to one another forming a solid mass. This is why the viscose rayon threads, as they come out of the spinnerets, are precipitated in a coagulating bath consisting of about 65 to 70 per cent water, sulphuric acid and sulphate of soda. Sometimes glucose, sulphate of zinc or sulphate of ammonia are also added to produce a softer and stronger thread. Each spinneret is of the size of a small thimble and has microscopic jets or holes varying in number according to the number of rayon filaments required in the yarn to be spun. There may be as many as 500 though 200 or less are more usual. The denier or count is determined by the number of these jets. The spinnerets are costly, being made of an alloy of gold and platinum.

Cake Spinning

The spinning proper is done through very ingenious machinery devised in imitation of the method used by the silk worm. The viscose is brought in pipes from the filters to the spinning machines each of which operates many spinnerets. A pump forces a constant stream of viscose through the minute jets in the form of hardly visible filaments which issue into the coagulating bath and solidify into groups of continuous and parallel filaments all lying close together These are next drawn over the glass rollers in the front of each spinneret and drop down glass funnels which rise and fall in front of the rollers The funnels lead to revolving cylinders known as spinning boxes. These boxes revolve quickly so that by centrifugal force the filaments are flung against the sides of the boxes becoming twisted at the same time. Thus, the boxes become filled with cylindrical hollow cakes of continuous twisted yarn which are removed to cabinets for conditioning and hardening. The cakes are then unwound and rewound into hanks which are washed and dried in ovens They are again

ashed and treated with a bleaching solution. This solution is afterwards removed by chemical treatment and the hanks are again washed carefully. They are then wrapped in clean cloths and put in hydro-extractors where most of the moisture is evaporated, any remaining moisture being finally dried off in steam-heated chests. We now have the final finished fibre, except for any hanks that may have to be dyed the required colours. The following is a diagrammatic representation of a Topham Box Spinner with the pipe towards the bottom and the filaments issuing in the acid bath are shown as being drawn over glass rollers in front of the spinnerets, to be finally passed through glass funnels into revolving spinning boxes. A finished cake of rayon yarn is also shown on the top right-hand corner.



Bobbin Spinning

So far we have considered spinning into cakes; but viscose rayon is also spun on to bobbins which may rotate in a liquid similar to the coagulating bath. But these threads are without twist which has to be imparted afterwards on special twisting machines, after they have been washed, bleached, etc. on the bobbins. The threads are then reeled into hanks. As by bobbin spinning the yarn is treated more gently than in box spinning, finer filaments can be spun as also the degree of twist can be regulated. Viscose rayon can now be made with any required lustre and of any desired fineness. It has a great attraction for moisture and dyestuffs Hollow filaments of viscose rayon are also now available with gas or air imprisoned in their walls: a small proportion of soluble carbonate is added to the viscose before projecting it into filaments and the acid bath contains a few other salts like zinc or magnesium sulphate: the action of the acid is to form a bubble of carbon dioxide gas in the filament which becomes elongated with the filament: the result is the production of a hollow fibre which is very pliable and which has the 'Scroop' or rustle of real silk.

Cellulose Acetate Rayon

Cellulose Acetate Rayon, though first patented in 1895, did not assume industrial importance till after the first world war. During that war, a large factory for its manufacture as dope for aircraft giving a *shrunk-finish* effect on the wing-fabric was erected at London, Derbyshire, at a cost of about eight millions sterling: after that war, this installation was switched over for manufacturing rayon by the acetate process in which many improvements were subsequently made The raw material for this Rayon is usually cotton or the best wood pulp which is also first bleached and mercerised The cellulose is heated in a jacketed container provided with a stirrer in a mixture of equal parts of glacial acetic acid and acetic anhydride in the presence of about 10 per cent sulphuric acid as a

catalyst. The result is a primary cellulose acetate which is soluble in chloroform. It is then heated with a further quantity of acetic acid and dilute sulphuric acid and treated with water. Thus, a secondary cellulose acetate becomes precipitated which is washed, hydro-extracted and dried. It is then mixed with acetone in revolving mixers so that a clear homogeneous solution is obtained. Pigments to produce dull lustre may now be added. Charges from several mixing vessels are blended and filtered again and again when the solution is ready for spinning.

How Spun

Cellulose acetate rayon is spun either wet or dry. In the former case it is precipitated into coagulating baths of oils, hydrocarbons or salt solutions, sometimes by the stretch spinning methods, and the threads are collected on bobbins, washed, dried, twisted, reeled, etc The dry spinning method is, however, now adopted almost universally. The spinnerets are situated at the top of specially constructed closed chambers provided with ducts at the bottom from which air rises, regulated as regards temperature and humidity. As the filaments travel downwards, the acetone solvent is evaporated by the upward current of warm air and the filaments solidify, to be wound on to bobbins. They practically require no further treatment as dry spinning produces an already finished article. The insertion of a twist is a separate operation unless cap-spinning is resorted to. After twisting the yarn is reeled into hanks.

Its Special Features

For some years, acetate silk did not yield to the majority of colours used for dyeing other varieties of artificial silk. It could therefore only be used for effect-threads in fabrics where some threads were to remain white after dyeing. In recent years this problem has been solved and special dyes have been evolved for this class of silk. The result is that acetate rayon can be mixed in fabrics with other rayons for producing mixed colour effects as the

dyes of the former will not affect the latter and vice versa. This yarn has a very attractive lustre and can be easily delustred It is soft and supple and, being a poor conductor of heat and electricity, it is especially useful for manufacturing underwear when it is warm and has a pleasant feel to the skin. It does not stand great heat when wet, so laundering requires great care. It is much less absorbent of moisture than other varieties of rayon or thin silk. It is also an excellent electrical insulator and is used either as wrapping or as lacquer. It transmits ultra violet rays better than glass and is therefore used as a film for this purpose These special properties of Cellulose Acetate are due to the fact that while the other rayons start and finish as cellulose, this rayon starts as a cellulose but finishes as a chemical compound of cellulose and acetic acid This rayon has become increasingly popular on account of the publicity received under one of the trade-names Celanese as in lustre and handle it is perhaps the nearest to real silk. The manufacture can however be regarded as only about 3 per cent of the total production of artificial silk.

Cupra Rayon

Cuprammonium or **Cupra Rayon** is generally produced from purified linters or cotton waste though specially purified wood pulp is used to some extent. The raw material is first treated with a dilute solution of alkali to remove grease and then dried. The basic principle of this process is that crystalline blue *copper sulphate* with the aid of caustic soda and ammonia can be transformed into a liquid which dissolves cellulose. The cellulose is first machine-ground into a fine pulp to make it more readily soluble. This pulp is mixed with copper hydroxide in a disintegrating machine and then filtered under heavy pressure in a hydraulic press. The press-cake so formed is dissolved in concentrated ammonia in a stirring vessel and the solution which is now deep blue in colour and of the consistency of honey is prepared for spinning by passing it several times through filter presses to storage tanks and then submitting it to vacuum. The solution is now con-

ducted to spinning machines for wet spinning and passed through the orifices of the spinnerets into a sulphuric acid or caustic soda coagulating bath, the thread being usually stretched in its passage from jet to bobbin, which produces very fine filaments almost of the same diameter as that of silk.

Its Properties

The yarn has some copper which must be removed. This is done by lacing the hanks and washing them after which they are bleached, soaped and dried. They are then wound on bobbins or cones and finally twisted. If the spinning is done direct on the bobbin, washing is effected by passing the yarn through a suitable bath, as it is being wound on the bobbin or after it has been twisted and reeled into hanks. In recent years centrifugal spinning has been adopted as for Viscose rayon, and all subsequent processes are performed in the cake form. The finished cupra rayon has the properties of cotton. It can be spun into very very fine filaments, even finer than 1 denier; its other distinguishing quality is smoothness, softness of handle, subdued lustre and good covering power A more favourable sheén is obtained by adding 2 per cent cane sugar, glucose or tartaric acid to the spinning solution. This rayon, though appealing to the exacting tastes of customers, is decreasing in consumption which is only about 2 per cent of the total output.

Nitro Silk

Cellulose nitrate Rayon or **Nitro Silk** is the artificial silk originally manufactured by Chardonnet. The raw material is usually cotton waste or linters. The basic principle here is the formation of **Nitro cellulose** or **Gun Cotton** by treating purified cotton with acids Nitrating of cellulose is done by a mixture of water and nitric and sulphuric acids whose relative proportions as well as the duration of nitration are very variable. Generally, nitration is carried out for about an hour at 40° or 50°C with a mixture of 15 to 20 per cent of water, 18 to 30 per cent nitric acid and 48 to 64 per cent sulphuric acid. After completion of the

nitration, the surplus acid is removed by squeezing out the nitrated cotton in presses and by centrifuging, the recovered acid being used again. The nitrocellulose is now washed with cold water and then with hot, and then torn up into as fine shreds as possible in bronze breakers or hollanders. These are now dissolved in a mixture of two of ether to three of alcohol, to make a 20-30 per cent solution for spinning In order to remove foreign matter, the solution is forced through filter presses by means of compressed air. It is now allowed to stand in tinned steel or tinned copper storage tanks where air-bubbles are removed by vacuum and the viscosity becomes uniform.

Its Properties

This kind of rayon is spun either by the dry or the wet process. In the former which is more usual, the filament as it comes out from the orifice of the spinneret is dried by a current of warm air, the alcohol ether solvent which becomes evaporated is taken to condensing towers for recovery though this is not always an easy matter. In wet spinning which was Chardonnet's own method, the filament issues in a settling bath of water which coagulates the nitro cellulose and dissolves the alcohol-ether solvent. The wet process also permits of **Stretch-spinning** by which the filaments can be drawn out to finer diameters. When the thread is hardened and dried, it is wound on bobbins. It can be used without further treatment but nitro-cellulose is highly inflammable and explosive so that it is necessary to remove the nitro groups from the spun cellulose This is done by denitration. A great many reagents have been tried but none with as much success as the original sodium, ammonium or calcium sulphide solution. Denitration requires utmost care and rigid control if the fibre is to escape injury. It involves a loss of weight upto 30 per cent and a decrease in stretch especially in the wet state, as its resistance to water is largely decreased. Uneven denitration would result in the fibre refusing to take up dyes evenly. The denitrated fibre is then washed, soaped, dried, sorted, weighed and packed up. In feel and

appearance, Chardonnet silk is said to be the nearest approach to real silk. Lehner, Vivier and other silks also belong to this category. In 1910 its output was 48 per cent of the total but now it may be reckoned as about 8 per cent, being next to that of viscose.

Staple Fibres

All the four kinds of rayon are turned out like silk in continuous filaments but, like spun silk, they can be and are also made as **staple fibre.** This is done by cutting the continuous filaments into definite lengths to correspond with the length of staple of cotton or wool and then by spinning them like the latter. Such material has this advantage that all the fibres in a lot are of the same length and there is complete absence of foreign matter. Though all the four classes of rayon can yield staple fibre, acetate staple has a tendency to be readily electrified and is therefore generally used for admixture. The filaments required for cutting for staple fibre are prepared in the normal manner in the early stages but after coagulation they are collected together and wound in parallel order on to reels, desulphurised and bleached in hank form and then cut, or they are wound on perforated drums, washing etc., being done by forcing the liquids through them Staple rayon fibre is available in very fine deniers, the variety known as Fibro being as thin as 1½ denier. Staple fibre has a great demand for mixing with other fibres. On account of the shortness of the fibres and the larger amount of twist, a thread of staple fibre has a rougher and more fibrous surface, a softer and a fuller handle and better warmth-giving properties than the same class of filament rayon, though the lustre is much more subdued. It has normally a smoother surface than cotton or wool and lacks therefore the grip or binding property of the latter, though chemical and mechanical treatment has been applied to roughen and crimp the fibres.

Twists

General qualities of rayon contain from 2 to 2½ turns per inch, though more twists are imparted for special pur-

poses. Thus, crepe rayon yarns which are largely superseding crepe silk yarns have an increased twist though more than 20 turns per inch in ordinary counts has a tendency to weaken the yarn progressively. In order to impart the increased twists, the yarn is treated with a light size whose film acting as a lubricant assists in controlling the twist. Staple fibre yarns are also crepe twisted, the number of turns per inch being often as high as 45 to 50. After twisting, the yarn is steamed so as to set the twist and prevent snarling or kinking up

Deniers

Rayon yarns are not reeled in fixed standard lengths but in such lengths that the number of hanks per pound or Kilo is the same. This method varies with the maker. but English hanks are made up in bundles of 5 or 10 lbs. weight with approximately 50 or 100 hanks to the bundle. The bundles must be kept dry as moisture has a deleterious effect on the tensile strength; and also the risk of fire must be avoided as artificial silk burns readily with explosive violence. The method of 'counting' is the metric Denier as in silk, the basis being the weight in half-decigrams of 450 metres of yarn. For convenience, this weight is taken in grams of 9000 metres. There are 9,072 half-decigrams in 1 lb. and 450 metres are equal to 492.13 yards, so that by multiplying 9072 by 492 13, a standard factor, 4,464,600, is obtained which divided by the denier count gives the yards per lb of a yarn Thus, in one lb of 150 denier yarn there are 4,464,600 divided by 150 equal to 29,764 yards*

Differences between Rayon and Silk

Artificial silk can be easily distinguished from pure silk, as we have already learnt, by its more brilliant and more metallic or glassy lustre. The modern tendency,

*If 4,464,600 is divided by 840 yards per hank, a standard factor, 5,315, results which, divided by a stated denier count, will give the corresponding equivalent cotton count and vice versa The relative standard factor for worsted is 7,972 5

however is by using finer filaments to produce a yarn more resembling silk. Ordinary rayon has a harsher, colder and stiffer feel than real silk and is more easily creased. All artificial silks lose a great deal of their strength when wet and require careful handling. They recover their strength on drying. A portion of the lustre becomes permanently destroyed when boiled in water or soap solutions for sometime, unlike as in natural silk. A thread of artificial silk, when wetted under tension, say by laying it across the tongue, will show a reduction in strength which real silk does not. Also on burning all rayon fibres do not, like silk, emit a smell of burnt hair or horn. All such rayons except cellulose acetate burn very quickly like cotton with little odour or ash; and Cellulose Acetate burns with difficulty, a thread when ignited forming hot molten globules at the charred ends, somewhat like burnt wool or silk but emitting a characteristic smell. This rayon is also soluble in acetone in which the others are insoluble, and its hygroscopicity or capacity to absorb moisture is only about 4 per cent as against 10 per cent for the rest.

Future of Rayon and Silk

Rayon fibre is not necessarily a substitute for silk though the early discoverers believed that it was destined to take the place of silk which would ultimately disappear from the market. This belief has not materialised for the simple reason that the two materials have their own distinctive uses. As has been aptly said, the principal users of both materials are women in whose nature there is a desire to be unique and to be differentiated from others by outward appearance; and, as in the case of pearls, the real pearls are still much sought after and highly prized even though only the experts can distinguish them from artificial ones It has also been said that in a democratic country like America there is a tendency for the poor and the rich both to dress alike, and as rayon has now the appearance and feel of real silk its cheapness has made it essentially the fabric for the lower and middle classes.

While the rate of expansion of the rayon industry is likely to slow down soon, so many new types of synthetic textiles are being manufactured, like lanital (produced in Italy from casein as a substitute for wool) and similar fibres from casein, chitin, or even minerals that Dr. Kennedy of Pacific mills, New York, thinks that in 10 years' time, apparel will be all made from synthetic textiles, while household and industrial uses will only constitute the principal markets for cotton. Rayon has further control on the industry in that it can be used in conjunction with other fibres, like silk, cotton, wool and linen, in producing a great variety of mixed fabrics while its own individuality in hosiery and knitted wear is unequalled. We shall give in the last chapter a short description of other uses of rayon.

World Production

Reference has already been made in the first chapter to the world production of artificial silk. The United States easily ranks first in the world both in the matter of production and consumption and continues to expand the industry with straddling strides. The world war may have given a fillip, for from 487 million lbs in 1940, the latest available figure for 1944 show a jump to 705 million lbs. The rate of production may be guaged from the fact that in a typical rayon spinning factory, the thread produced in one hour would be sufficient to completely girdle the earth! In India we do not yet manufacture rayon yarn but we have mills for manufacturing piece goods and hosiery from imported yarns. Our imports of both yarn and piece goods are increasing and show an annual intake of about 50 million lbs.

Nylon

No chapter on Artificial Silk can be complete without some reference to the latest development in this sphere, namely the production of plastic filaments and yarns by extrusion from some plastic material or by coating cotton or rayon threads with some form of plastic. Many years o

intensive research have been devoted to reproduce artificially the molecular chain of real silk. Silk is known to be related to proteins which are complex substances containing amino-acids. Though the German chemist Fischer succeeded in making amino-acid molecules join together to form large molecules resembling those of protein, the real credit of producing such molecules (superpolyamides) which would closely resemble real silk goes to America. The substance so prepared from the basic constituents, coal, air and water, is known as Nylon. The threads are drawn out from a molten mass so that the long molecules exert attractive forces on one another, making the filaments very strong, twice as strong as natural silk.

Its Uses

Nylon yarns when woven have a delightful softness and handle and their greatest use so far has been in making stockings (which do not develop ladders) and gossamer lingerie. Their great tensile strength makes the sheerest materials made from them durable and hard-wearing. Their resistance to water and ease in drying make washing easy. During the war parachute covers were made from nylon. Though the output of the raw material is very restricted, nylon is made into tennis guts, surgical sutures, fishing lines and sewing thread. Mixed with wool or rayon it makes excellent material for gentleman's wear. Nylon fibres are also extruded hard or stiff to serve as bristles for brushmaking. Uniformity of diameter and resistance to chemicals give nylon bristles double the life of other bristles Nylon brushes include tooth-brushes, hair, clothes and nail brushes, paint brushes, bottle-washing machines and gun-cleaning brushes Nylon is also prepared as a moulding powder but this development is still in an experimental stage, though spools used for winding coils for actuating air craft instruments have been successfully prepared from nylon powder. The basic colour of nylon is a light amber and it is not very easy to incorporate other dyes

Other Plastic Yarns

Side by side with the development of Nylon, America is also manufacturing many other varieties of plastic yarns. Thus 'Saran' is a plastic with a petroleum, brine and chloride base Its monofilaments are formed by extrusion and are used for weaving extremely strong cloths e.g. for the furnishing trade. The woven material is lustrous with a pleasant handle, light in weight, hard-wearing, resistant to chemicals and easy to clean. Even if a bottle of ink is spilt over the upholstery, a damp cloth removes all the stains. Filter cloths for industrial plant and window screens to replace wire-mesh, as well as tropical tents, have been made from Saran This plastic is also available in the form of powder for moulding or as extruded tubes and pipes The latter can be made rigid and, having great strength, may replace iron pipes in many spheres. Acetyline treated with acetic yields a plastic yarn '**Vinyon**' which is used for weaving filter and screen cloths, ladies' gloves and shoe-uppers, men's ties and dental floss Another plastic yarn is prepared from casein and is known as '**Aralac**'. It is used in combination with wool, silk and mohair in making economical garments Finally, **Plexon** yarns are those where cotton, rayon or glass fibres are coated with plastic by being run through a large composite machine with a trough at each end containing the plastic. The fibres pass through the trough being drawn through dies and drying chambers and can be run through over and over again to take any shape, cylindrical, elliptical, triangular or square. Plastic-coated yarns become proof against dampness, vermins, fire, acids, perspiration etc. and have over 120 colour ranges, being also available in transparent or translucent coatings

CHAPTER V

FABRICS

Early History

The manufacture of silk and artificial silk fabrics from yarn by **weaving** is a very technical matter and we can only describe here the barest outline. The silk weaving industry, born and nestled in China, was taken by Saracen weavers to Sicily where heavy damasks and brocades for gorgeous robes began to be manufactured. The art spread from here to Italy, Spain, Switzerland, France and the rest of Europe, but all the weaving, because of its artistic character, was done on **hand-looms**. Swiss machinery makers attempted the construction of **power-looms** for silk but were unsuccessful for a long time. They were at last able to produce machines particularly suited for satins and by 1881, 3000 power looms were working at Zurich as against 30,000 hand looms. More and more improvements were made and in another 25 years the number of power looms and hand looms became equal. At Zurich, Lyons and other centres today, the power loom has completely triumphed over the hand looms and in America where silk weaving was not introduced till late in its history the factories that were built were all equipped with the latest machinery.

Indian Hand-looms

In India on the other hand the position with regard to natural silk is just the reverse. Apart from a few small mills operating power-driven looms, the handloom weaver is the main consumer of all the raw silk produced by our sericultural industry. Though there is no reliable data, the number of hand-looms working on silk is said to be about 50,000. This industry moreover is not organised and is in

the hands of the merchants who supply the weavers yarn and who take over the finished articles, paying either a fixed rate or a daily wage. In Kashmir, the hand-loom factories where 10 or more looms are work owners through paid labour. In Benares, the weavers their own materials and sell the finished articles i open market unless they are requisitioned to manufa special quality goods. In Surat, the weavers are either daily wages or are engaged on contracts for three mon The raw materials used by these weavers are raw twisted silk and gold thread which may be either Ind made or imported, and spun and artificial silk which is imported. It has been stated that on the whole Ind handloom silks have better lustre, tenacity and elastic than imported silks. The operations preliminary to wea nig on the hand looms consist of twisting and windin boiling off, dyeing, doubling and warp preparing. These a all done by the hand and some weavers are indeed adept a preparing yarns for their looms.

Essential Conditions

In silk-weaving by machinery, two conditions are essential, viz good light and cleanliness. In the other textile industries the machines are usually driven by shafting fixed to the walls or carried by pillars which keeps the air continually in motion, shakes dust on the fabrics and obstructs light This would not do for silk which, being a costly fibre must be woven clean. Underground belting was tried but it was found difficult to oil the bearings Now the difficulty is overcome by providing separate drives, each loom having its small electric motor so that there is neither dust nor obstruction to light. Moreover in modern factories, the weaving sheds are lighted from above so that defects in the weave become easily apparent and can be remedied at once. Certain materials however like miller's gauze require to be worked in underground cellars where the damp air can keep the fabric moist and so facilitate the introduction of the weft: these too must be adequately lighted.

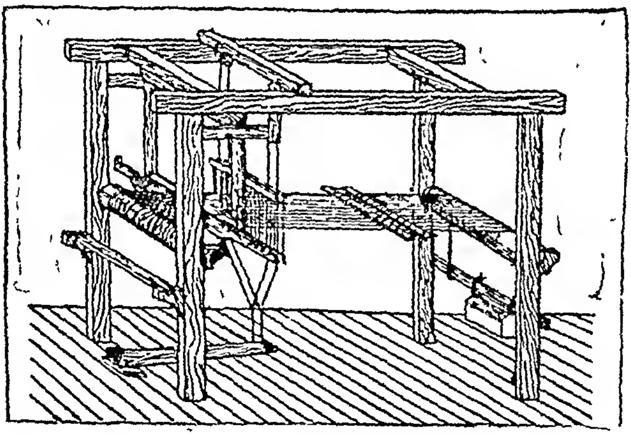
Yarn Preparation

The raw material is received at the factories in the ... hanks and sometimes on cops. This has to be pre- ... as a preliminary to weaving. Every woven fabric is ...d of the warp threads which run parallel to the ... of the piece and the weft threads which run across the two systems of threads intersecting at right angles and being interwoven with each other in a permanent fashion These two sets of threads are for silken fabrics known as organzine and tram respectively. The yarn received at the factories has to be prepared either for the warp or for the weft. The preparation for the warp takes a considerable time as it consists of several operations. The hank yarns are first wound on bobbins with flanged ends and from them are wound on warp bobbins. This double winding secures even tension and also acts as a cleaning process. The next operation is warping which means winding on the warp beam of 'ends' or lengths of yarn sufficient in number to make a fabric of the desired width, the length of the beam being equal to the width of the fabric and that of the ends to the length of the piece. The essential conditions to watch while warping on the beam are to see that the ends lie parallel and are distributed evenly and with a uniform tension. We shall not describe the actual process but shall merely mention that this distribution is to be spaced out according to the weave or the pattern that is desired to be manufactured. The weft thread is also first wound from the hank on to a bobbin and thence to a wooden or paper bobbin which can be fitted into the boat-shaped shuttle in such a way that the yarn which it contains unwinds itself steadily and evenly when the shuttle flies backwards and forwards in the loom to insert the weft in the piece.

Looms

As regards the looms proper, there is hardly much difference in the construction of the hand and the power looms except in the means by which they are driven. And

indeed hand looms are now built exactly like power looms but are operated by the feet as shown in a simple hand-loom illustrated below. Whether hand- or power-loom, the operations of weaving are mainly four. As soon as the loom is started, the warp threads begin to unwind from the warp beam The shafts then rise and fall raising and lowering the warp threads in a predetermined sequence so as to form opening or 'sheds' through which the shuttle carrying the weft yarn passes over the depressed set of threads from one shuttle box across the loom to the other. This operation is known as **'picking'**. The **reed** now moves forward and beats up the weft, that is, pushes it close against the weft which has been previously inserted. And finally, the fabric as it is being made is continuously wound on the **cloth beam.** The cycle of these four operations is repeated again and again till the whole piece is completed.



Kinds of Weave

The looms can be made to produce any given design of fabric, the 'weave' being determined by the scheme according to which the threads cross and recross Generally, the structure of a cloth and its ornamentation by weaving is worked out by the cloth designer on squared paper, though

in the village hand-loom industry the designing is a matter of inspiration and memory. Where squared paper is used, successive vertical lines of squares represent the warp threads and the horizontal ones the wefts A filled in square would mean that the warp thread it represents is above the weft, a blank denoting weft above warp. Differnt colours are used to show more than one warp or weft. There are countless varieties of weaves but they can all be derived from three fundamental types (1) plain, linen or taffeta weave, (2) twill or serge and (3) satin There are two other types also in use, namely **piled fabrics** like carpets and velvets and **crossed weaving** as in gauzes and nets.

Plain Weaves

In the first category of plain, linen or taffeta weaves which are the oldest and simplest, each weft thread passes alternately above and below a warp thread as is done in the weaving of plain mats. This weave gives a similar appearance to the fabric on either side. From this weave are derived the **'rib weaves'** and the **'panama weaves'**. In the former the rib may be either in the warp or in the weft; in the latter it is in both. The rib effect is obtained by repeating the linen or plain weave several times without change along the piece. If it is warp rib, the warp threads are floated or lie loose over from two to four weft threads and have the form of flattened curves: so that the colour and other characteristics of the warp predominates The Panama weave which combines the warp and weft rib produces a decorative dice effect, the size of the checks depending upon the method of floating. In **poplins, repps** and **cords** which are but a modification of the plain weave, a corrugated appearance is brought about by alternating thick and thin threads of warp and weft. Stripes and checks can similarly be produced by introducing colour, and even in tapestry of ancient Egypt which was also a 'plain weave', each horizontal line of weft was made up of numerous short lengths of parti-coloured threads.

Twill Weaves

In the twill or serge weaves, the weft threads do not pass over and under each warp thread alternately but pass over three or four warp threads at once and then under the same number and so on; at the same time, in passing from one weft thread to the next, the points of intersection shift one space onwards so that a diagonal effect is produced The twill effect may be in the warp threads or in the weft threads. In the former, the warp crosses two or more wefts before one of these comes to the surface; in the latter the weft behaves similarly. **Reversible twills** where two or more warp threads are followed by two or more weft threads and the intersections shifting by one point produce a diagonal effect are rare in silk-weaving. In Crossed twills the pattern becomes a zigzag instead of straight lines producing a wavy effect and in **Reinforced** twills the diagonals are not a line of single intersection but of several. Twills can also be broken up into lozenges, squares and other geometrical designs, thus producing pleasing and soft patterns

Satin Weaves

In the satin weaves the intersections recur regularly but are nowhere in contact and are not visible, either only warp or only weft appearing on the face and the other set of threads going to form the back. The surface is thus smooth and polished for want of intersections This weave is very common where two kinds of material are used, the more valuable one being brought into prominence and the other remaining almost concealed. The silk damasks which are made on the Jacquard loom* by weaving dull designs or figures on a lustrous satin ground by using the reverse side of satin weave also belong to this class; so do

***Jacquard looms* are those which enable complicated designs and patterns to be woven: as against *Tappet* or *Dobby* looms which weave plain cloth or those where the designs can be repeated only on eight or lesser number of picks. Before the jacquards were invented, large figured effects on fabrics were produced on what were known as *draw looms* which meant laborious and slow work.

brocades, which though made with the satin weave, have interwoven threads of gold and silver.

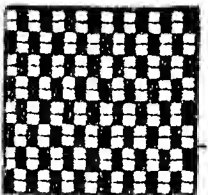
Pile Weaves

In all weaves so far considered, the warp and weft have been laid in longitudinal and transverse parallel lines. In piled fabrics however portions of the weft or warp assume a position at right angles to the surface of the cloth. Thus velvets and plushes are made with two warps or wefts as the case may be forming the pile which is usually of mercerised, cotton, rayon or silk so that a lustrous surface is produced. During weaving, wooden or metal rods are inserted between the picks so that the pile warp threads pass over them and, when the rods are withdrawn, loops are left forming the pile. The loops may either be cut or uncut according to the nature of the fabric desired. In plush, the pile is longer than in velvet but not so close. Plush is often made with double fabrics, being woven with two wefts and two warps; one group of threads passes through the two fabrics alternately and binds the two together; when these two are cut apart, half of the connecting threads remain in each fabric. Figured warp-pile fabrics, like carpets, are made with regular and irregular cut and looped surfaces, the particular effect being brought about by colour in a variety of ways.

Crossed Weaves

The last group of fabrics includes crossed weaves like gauzes and nets where the warp threads inter-twist amongst themselves to give intermediate effects between ordinary weaving and lace. In the gauze weave, the warp threads are in pairs and one thread of each pair makes half a complete turn round the other after the passage of the shuttle, so that the warp cannot slip along the weft. Leno is a fabric composed of an odd number of picks of a plain weave followed by one pick of gauze. Fancy gauzes may be made by using crossing threads of different colours or counts or introducing other kinds of weave, etc. Lappet weaving consists in ornamenting the surface of a plain or gauze fabric

with simple figures by drawing certain warp threads into a transverse position and then lifting them over a thread of weft and moving them in the opposite direction. It will be apparent that in order to bring about a diversity of form and texture in the fabrics, no intricate machinery is necessary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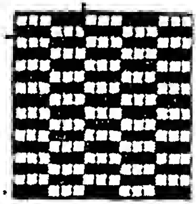
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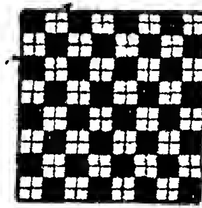
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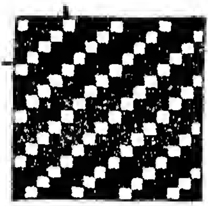
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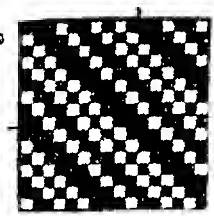
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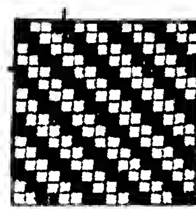
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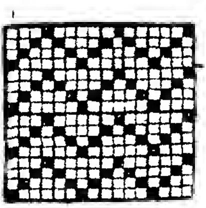
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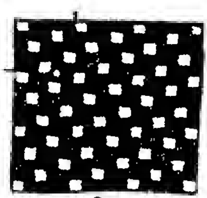
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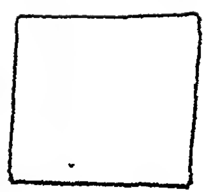
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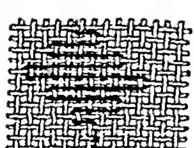


as the most elaborate specimens of the weaver's art can be and are produced upon simple looms. In the above illustration the first two diagrams are rib weaves (warp and weft), the third is Panama, fourth warp twill, fifth reinforced twill, sixth reversible twill, seventh crossed twill, eighth warp satin weave and last Lappet weave.

Finishing Processes

Silk fabrics, after they are woven, require finishing, unless they have been made from yarn previously dyed in the hank form. Most of the fabrics turned out on power looms are not so made and require finishing. For this purpose, pieces of the same width and quality are sewn together end to end and rolled up into one continuous length. Then the fabric is made to go through the process of gassing by being passed carefully over a number of small gas flames set close together, so that any foreign matter like dust or down is burnt up without the cloth being singed. The fabric is now moistened and **calendered** by being passed through steam-heated rollers so that the material through pressure becomes stronger and closer. A better handle is now imported by sizing which is done either on one side or on both sides; in the first case the size is simply poured over the material, any excess being scraped off with a knife; in the second case the size is pressed in by two rollers revolving in a trough. There are a number of sizing mixtures available, composed of starch, glue, gum, paraffin, etc. and each manufacturer has his special mixture. After sizing the material is **dried** through steam heated rollers, and due to the shrinkage acquired thereby is again moistened and **stretched** *on* "**stentering** frames' heated by gas or steam pipes A final calendering gives a full handle and correct lustre, a friction calendar composed of one steel roller and the other covered with paper being used when a high lustre is required. Some fabrics especially the ribbed or fluted ones are merely steamed in strongly heated stationery steel rollers instead of being calendered in order to avoid the crushing of the pattern. Some again which have become

stiff and brittle through sizing have to have the size broken in through special machines carrying blunt knives spirally arranged or fitted with projecting studs. The last operation of pressing is carried on in powerful presses worked hydraulically which gives a smoother surface and a fuller handle. The fabric is now ready for wrapping on cards and packing. Fabrics woven on the handloom are often sold straight from the loom, being given no finishing treatment beyond picking off loose ends and trimming up.

Special Finishes

Though the above description explains certain finishes common to most silk fabrics, there are special finishes peculiar to particular fabrics There is, for instance, the moire effect which gives an iridiscent lustre with a wavy or watered appearance. This is brought about by folding the material in such a way that the weft threads of the two folds do not lie parallel: when pressure is applied to it through a calendar, the points of intersection which meet at an obtuse angle receive unequal pressure and there is thus a different reflection of light at different points. If the pressing is done between rollers which have patterns engraved on them, the moire effect is further "goffered" through the imprinting of the engraved patterns. Goffering is also done on velvets which acquire a pressed pile. Certain silk fabrics like umbrella materials or waterproofs are made impervious through treatment with aluminium formate or acetate in conjunction with soap or wax. Some again like theatrical clothing are made fire-proof through treatment with sodium stannate, and wringing with further treatment with ammonium sulphate and drying. Dyeing which is an art by itself is now done on the piece and before the dyes are applied, the fabric is gassed and then boiled off so that it becomes degummed. Dyeing is done either in the vat or in the jigger. In the latter case the fabric is wound and unwound several times on rollers in the dye-bath being kept stretched at the same time so as to secure an evenness of surface If the silk is to be weighted this is also done at

the same time as dyeing. The materials used for weighting are usually ferric nitrate and Chinese Gall. Tin weighting which was common at one stage destroyed garments by crumbling them to pieces after some time and is therefore now avoided. As regards printing which again is an art in itself, it is done either through roller printing machines, through perrotines which are engraved plates invented by one Perrot of Douen or, as in India, by hand.

Rayon Weaving

We have so far devoted our attention to the manufacturing of fabrics from natural silk While the general principles of weaving remain the same for fabrics made from artificial silk, there are certain special properties of rayon yarns which call for special treatment. Originally these yarns were used only as weft in silk and cotton weaving but soon they began to be used as warp as well. Existing machines were therefore found unsuitable and special modifications had to be made and special preparatory machines had to be used in order to avoid the formation of shiny spots, stripiness or irregularity in the finished fabrics. These defects are easily formed since rayon yarns are uniform in thickness and appearance and, being clear and smooth, are somewhat slippery. Moreover, rayon has a tendency to become permanently stretched through over-tensioning or through undue friction. This is especially so where the relative humidity of the atmosphere is liable to unequal variations so that it becomes necessary to maintain an ideal working room temperature at about 68° F. and a constant relative humidity of about 60 per cent.

Special Requirements

Loom manufacturers supply standard models of looms specially constructed for weaving rayon. In such looms friction must be reduced to a minimum so that special reeds [illegible]d shuttles are necessary and there should be efficient [illegible]kes capable of stopping the looms in a fraction of a pick. [illegible]icial silk usually requires a sizing treatment prelimi-

nary to weaving. The sizing mixture varies in composition but usually starch, like potato flour, glycerol, glue or gum, and sulphurated oils like linseed and olive oil (or monopol oil) are used. In both warp and weft winding, it is necessary to avoid plucking the thread which is therefore run more slowly than silk or cotton Also the warp thread is wound twice in order to ensure an even tension. As few knots as possible should be made and unless care is taken in warping, slight differences of colours or twist might lead to stripiness in the weave. For the weft thread, uniform tension on the bobbins is necessary and, as rayon weft is springy and tends to balloon as it is withdrawn, special shuttles with various forms of shuttle pegs for inserting the weft tubes have been devised. While weaving, the piece is not allowed to become too moist or too dry and, where the weft is also rayon, the speed of the loom is not allowed to be reduced. Care is necessary to avoid the marking of the cloth by the various rollers and machine parts. The weaving of rayon yarn has become a specialised art in which many Indian labourers have become perfectly adept. Rayon is now woven as an all-rayon fabric or in conjunction with silk, cotton, wool, linen and other fibres.

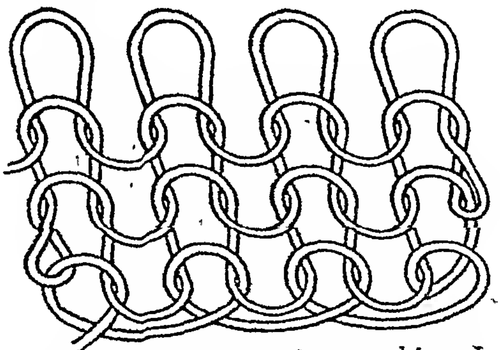
Ribbon Weaving

We have so far spoken of weaving what are known as broad fabrics There are however narrow fabrics, about a foot or under wide which are known as **ribbons**. These are woven either on hand or power looms specially designed and are made from natural as well as artificial silk or a combination of both along with cotton or velvet. In the ordinary loom only one broad piece is woven at a time: in a ribbon loom, there are several ribbons in the loom at once, each having a small shuttle of its own Thus several ribbons are woven simultaneously, sometimes as many as 100 to 120. And as there are a number of weft bobbins, empties require refilling more frequently so that ribbon looms work less rapidly than ordinary looms Velvet ribbons require looms with shearing arrangements. Apart from the shuttle

peculiarity, ribbon looms are similar in construction to ordinary looms and work on the same principle. Ribbons with coloured or figured designs require several kinds of weft and therefore two or more shuttles each. The finishing of silk ribbons is somewhat like the finishing of silk fabrics but satin weave ribbons are only brushed and shorn. Velvet ribbons are sized, dried, steamed and shorn to produce an even surface.

Knitted Weaving

The last class of fabrics is **knitted wear** like hosiery, ties, pullovers, shawls, caps, jumpers, etc. where artificial silk has greatly encroached on the other fibres We have learnt that in normal weaving, the warp and the weft threads intersect at right angles. In knitted goods, the two sets of threads do not intersect at all but link up to each other in the form of two letter S's, one turned towards the other, (as in an eyelet of a hook) and this interlooping forms a fabric as shown below:—



The first inventor of the knitting machine, Lee, found no encouragement or recognition either in his own country or in France to which country he had migrated. Although he died as a pauper, it is his principle that is embodied in all the modern automatic machines. These machines are of three types. Firstly, there are machines with needles fixed relatively to each other or with independently movable

needles where the knitted article is shaped by increasing or dcreasing the number of stitches so that the articles can be taken out of the machine in a finished state. The best machine of this type is **the Lamb** which can turn out stockings, coats, trousers, caps and all children's garments. Then there is the **circular machine** which produces a tubular web from which the desired articles are produced by cutting out parts and stitching. Another class of machines can produce pieces made to shape which have to be put together by sewing. In knitted wear too, designs can be produced by changing the system of stitches. Knitted goods require special finishes and where they are 'cut' and not 'wrought' goods, sewing and shaping also form part of the finishing process. Semi-wrought goods which are shaped on the machine have also to be sewn together at certain points on special machines. In order to prevent the edge stitches from breaking, edging becomes necessary which is also done on special machines. Some goods require roughening on one or both sides; this is done on machines composed of a number of small teaseled cylinders. All hosiery requires shaping: thus, stockings are stretched on forms, damped and placed in drying chambers when they acquire the desired shape. The final finish for most knitted goods is imparted by pressing which is done through hand, hydraulic or steam presses. Knitted wear is produced by hand-knitting as efficiently as through automatic machinery.*

*For a full description of the subject, the reader is referred to the book on "Knitting and Sewing" published in this Series

CHAPTER VI

MISCELLANEOUS

Chemical Composition of Natural Silk

We have learnt that the silk-worm spins a cocoon in its pupal stage by laying a thread of silk over itself in the form of figure 8's. This thread represents the contents of its silk glands and is ejected through the fine orifices of the spinnerets. When viewed under the microscope the thread (or bave) presents the appearance of a structurless vitreous cylinder consisting in reality of two filaments (brins) separated only by a fine channel. These two filaments are composed of **fibroin** which is relatively soft, while the fine channel is filled with **sericin** or silk gum which is said to be derived from the former through oxidation. Sericin forms the outer portion and has to be got rid of in the processes described as degumming. Besides these two substances there are small quantities of waxy and colouring matters in the silk thread. Mathews in his book on Textile Fibres gives the chemical composition of silk as water 12 5 per cent, sericin 22.58 per cent, fats 0.14 per cent, fibroin 63.10 per cent, resins 0.56 per cent, mineral matter 1.12 per cent; but this composition is not constant. Fibroin which may form even upto 70 to 80 per cent of dry silk has, when degummed, the soft pearly lustre of pure silk. It has low electrical and thermal conductivity. It is insoluble but swells slightly in water, alcohol, benzene and other organic liquids. Though chemically heterogenous, it is regarded as a colloidal protein with an approximate formula $C_{15}H_{23}N_5O_6$. It dissolves in concentrated solution of mineral acids or caustic alkalis and in an ammoniacal solution of copper oxide, from all of which it can be reprecipitated in a more or less altered form. It melts on heating, giving a smell of burnt feathers.

The fibroin of wild silks is similar in properties to that of mulberry silk but is more resistant to chemical action; the filaments of these silks are thicker and possess longitudinal striations along which they tend to split into fibrillæ under chemical or mechanical action. Sericin is also a protein with a composition similar to that of firboin but with a little more oxygen It is more chemically active than fibroin and can be separated from the latter by the solvent action of hot water or of acid or alkaline solutions Its hot aqueous solution gelatinises on cooling. In the case of yellow silks, it is stated that the colouring matter is due to the presence of carotene or an allied substance as neither fibroin nor Sericin is by itself yellow. Sericin is said to be secreted from two separate glands known as the **glands of Fillipi** and helps the two viscous filaments of fibroin to adhere together when brought on secretion into contact with the atmosphere. It may be mentioned that in chemical composition mulberry leaves on which the silk-worms feed are regarded as similar to fibroin, when analysed into the primary elements carbon, hydrogen, oxygen and nitrogen—which led the early pioneers attempting to manufacture artificial silk to use mulberry cellulose as a base for preparing a colloidal solution from which filaments could be drawn.

Certain Properties of Artificial Silk

We have already learnt that the four chief varieties of artificial silk are all derived from vegetable cellulose: their chemical composition is therefore very similar to that of the latter.* There is this difference however that while viscose, cuprammonium and chardonnet rayons are all regenerated or reverted cellulose, acetate rayon is a mixture of esters formed by compounding cellulose with acetic acid, and its qualities and properties are therefore different from those of the other three. Its specific gravity for instance is 1.36 while that of the latter, about (1.52), approxi-

*For a description of the composition and properties of cellulose the reader may refer with advantage to the book on 'Fibres' published in this Series

mates that of cellulose (1.58). The specific gravity of real silk is 1.40. Acetate silk is very little absorbent of water while the other three kinds absorb it much more readily, the hygroscopicity of the former being about 4 per cent while that of the latter 10 per cent. Though like real silk, acetate silk is as strong wet as when dry, it is not so strong as the other silks when dry. Unlike natural silk, artificial silks are not very elastic, the expansion upto breaking point of dry fibres ranging between 18 to 22 per cent: they will resist tension with very little stretch upto half the breaking load, but beyond this the stretching is rapid and permanent, producing 'bright' threads or 'shiners' in the weave. Capacity to bear tension is also reduced by exposure to friction. The covering power, that is to say, the capacity to cover up the interestices between the threads of a cloth, is less in rayons than in silk because the filaments are thicker and of greater specific gravity, but this power can be improved by increasing the fineness and number of filaments in the denier. It must however be remembered that while the properties of real silk, resulting as they do from processes of nature, are not capable of being varied, those of artificial silk can be and are being continually improved through experimentation and research. Nevertheless, though the different varieties of artificial silk aim at simulating real silk in more respect than one, none has yet been produced artificially which can claim all the excellences inherent in the natural fibre. It is therefore claimed that at no point of time however remote is there any fear of natural silk being completely dethroned by fibres artificially and even artistically prepared.

Diseases of Silk-Worms

There are at least four diseases to which silk worms are liable and all these are also found among the silk worms bred in India. The most serious of these is **Pebrine** which in the middle of the nineteenth century caused serious damage to the silk industries of France and Italy and menaced the very existence of the silk-worm in the world. The scourge became a calamity on such a national scale

that the French Government had to commission the famous bacteriologist Pasteur to undertake an investigation into the causes and cures. After three years' study, he was able to isolate the bacilli of two diseases and his recommendations were merely commonsense; to avoid breeding from infected seeds and to isolate the healthy ones through strict supervision Thus, it became possible after a long and laborious method to produce a healthy stock of valuable races from highly-infected breeds. For, the disease is not only parasitic and contagious but hereditary. Pebrine manifests itself by dark spots in the skin of larvae: the eggs. if they hatch at all, do so imperfectly. The worms are weak and stunted, languid in movement and fastidious in feeding If cocoons are spun by infected larvae, they are soft and loose and the moths are feeble and inactive. The disease is more virulent in the second generation. The only effective remedy is to use disease-free seed. Pebrine has caused much havoc in Kashmir and Bengal. In the former state, the Government now supplies disease-free grain. In Bengal only fifty per cent and in Mysore only 27 per cent seed is disease-free and of this too quite a good portion is unproductive.

Another serious disease is Flacherie which is akin to Cholera and therefore contagious. Pasteur proved that it was caused by "ferments and vitrios" found a-plenty in the fermented juice of the mulberry leaves. The disease is ascribed to the feeding by the worms of damp leaves or of leaves freshly plucked and not allowed to wilt slightly. The Japanese specialists put it down to careless or inefficient rearing among insanitary surroundings The worms absorb large quantities of water along with the leaves and this water must be transpired or perspired through good ventillation: otherwise, the digestive processes will be stopped and the microbes will multiply enormously on the leaves remaining undigested. The most effective remedy threfore would be proper hygiene apart from the use, if necessary, of quicklime to facilitate the transpiration of the silk worms.

Grasserie or fatness—a kind of dropsy—is yet another disease of the silkworm. It is more prominent after the fourth moult when the skin of the attacked worm becomes distended and shiny. The blood loses its transparency, becomes milky and tries to ooze out through the pores. The cause is said to be unsuitable food and sudden changes of temperature. The disease is not very dangerous and the larvae who spin feeble cocoons die within them.

The last disease is **muscardine** which is caused by a fungus or mould developing in the body of the worm and causing its death. The disease is contagious and infectious, being spread through the spores of the fungus. It has caused a certain amount of loss in Bengal and Kashmir but has not become a serious epidemic there.

Apart from these diseases, damage is also caused to sericulture in Assam and Bengal by a **fly pest**. The fly lays eggs on the body of the silk-worm and the hatching maggots eat their way into the tissues, living inside during their larval period of about seven days. If during this period, the infected silk-worms spin cocoons, the maggots eat their way out of the cocoons, thus rendering them unreelable. The remedy suggested by the Bengal Government to make rearing houses fiy-proof by using wire gauze does not appear practicable, at least for the poorer rearers.

The total loss in the rearing of silk worms due to these and similar causes is indeed considerable. It is the least in Kashmir where it is estimated at between 20 and 30 per cent; in Mysore, the estimate is 40 per cent but in Bengal, it is as high as 55 per cent. It is these heavy losses that raise up the cost of production unnecessarily.

Varieties of Silk Worms

In describing the production of silk, we have confined our attention mostly to the mulberry feeding silk-worms as they are the most important and yield by far the best quality of silk. We have also referred to other silk-worms like Tussah, Eri, Muga, Yama-mai, etc. Numerous species

of moths, over 200 in number, have silk-spinning caterpillars but only a few of them are commercially important. All of them belong to one of two families, **Bombycidae** and **Saturnidae.** While the members of the latter family are all silk-spinners, they are known as Wild-silk moths as their silk is relatively of an inferior quality. The family Bombycidae on the other hand includes some non-spinning moths as well, though its silk spinners feed on mulberry leaves and produce the best silk.

The following table names the important silk spinning moths in each family:

Bombycidae	*Saturnidae.*
Bombyx mori	*Antherca mylitta.*
,, *fortunatus*	,, *Assama*
,, *textor*	,, *pernyi*
,, *arracanensis*	,, *yama-mai*
	,, *mezankooria*
	Attacus atlas
,, *sinensis*	,, *cynthia*
,, *croesi*	,, *ricini*
,, *meridionalis*	*Anaphe infracta*

We have already described **B. mori** which is the best silk-producing worm and is domesticated in all countries where the climate is congenial It is univoltine.

B. Fortunatus is the **Dassee** or **Desi** worm of Bengal—the **Chotopolo**—often called November Bund or cold-weather worm. It yields several crops in a year and produces reelable cocoons.

B. textor, the **Baropolo** of Bengal, is also domesticated in Southern China. It is univoltine and yields a soft flossy but reelable cocoon

B. arracanensis is the Burmese worm, also found in China It is multivoltine. Its cocoons are dark yellow and reelable but not so compact.

B. sinensis is called the **Chinese monthly worm** or **Sina Cheena** and is also found in Bengal. It is multivoltine and

its reelable cocoon is soft and loose, the colour being dirty yellow.

B. croesi is the multivoltine Madrasi worm of Bengal and China and, opposed to **B. fortunatus**, is called the **March Bund** or the hot-weather worm. The cocoons are golden-yellow and of good shape.

B. meridionalis is indigenous to Madras and Mysore. It is multivoltine. Numerous experiments are made to hybridise it with univoltine or bivoltine races imported from China and Japan and a great improvement in yield is thereby obtained especially in Mysore.

Among the **Saturnidae**, the most important is **Antherea mylitta** the Tussah worm which is indigenous to India. It is bivoltine and yields reelable cocoons of a fawn or silvery grey colour.

A. pernyi is found in North China and yields the famous 'Shantung' silk. It is bivoltine and yields compact reelable cocoons of a dark fawn colour

A. Yama-mai is indigenous to Japan It is univoltine and gives well shaped reelable cocoons. The silk is of excellent quality being greenish yellow in colour.

A. mezankooria is peculiar to Assam where it is known as **mezankoorie.** It is multivoltine and the cocoons are reelable.

Attacus atlas is the largest worm of all the silk-spinners. It is found in India, Ceylon, China and Java. It is multivoltine but the large cocoons are badly shaped and are difficult to reel.

A. cynthia is the **Cynthia** moth domesticated in China and also found in India. The cocoons are not reelable and are dark fawn in colour.

A. ricini is the **Eri-Silk** worm (sometimes called **Arrindi** from the castor oil plant Erandi on which it feeds). It is semi-domesticated in India, China and Japan. It is multivoltine but the cocoons are loose and flossy and not reelable. A cross between this and the last one (**A. cyn-**

thia) has produced the Ailanthus worm which has been successfully introduced into Europe.

Anaphe infracta is found in West and East Africa. The worms congregate into colonies building large common nests of silk inside which each individual spins its own cocoon. The latter is not as valuable as the outer parchment-like nest. The silk is dark brown, coarse and unreelable.

It has been established that while the rearing period is longer in the case of univoltine races thus involving greater expenditure in feeding and rearing, their cocoons are heavier and the filaments appreciably longer than those of multivoltine races The Bengal univoltine Barapolo yields 2 grains of silky substance per cocoon as opposed to the multivoltine Chotopolo which yields between 1.25 to 1.75 grains. While the Mysore indigenous multivoltine yields a filament on an average 394 metres long of 1.90 denier, the filament of the imported Japanese univoltine is 591 metres of 2.41 denier. The largest cocoons are obtained in Kashmir from the imported seeds (Gran Sasso and Abruzzo) whose cocoons weigh 153 and 195 to the lb. respectively, yielding 1,000 metres of filaments each while the Indian multivoltine cocoons weigh as many as about 500 to the lb.

Silk Gut

We have learnt that silk worms possess silk glands which are long thick-walled sac-like vessels running along the sides of their bodies. When the worms reach maturity, these vessels become gorged with a clear viscous fluid which has the property of hardening on exposure to air. It is from this fluid that the worms spin their cocoons. Advantage is taken of this property to prepare silk-gut used for casting lines in fishing or for such purposes as require a light strong and flexible string. Fully developed larvae are caught and killed. They are then hardened by steeping in strong acetic acid for some hours. Their silk glands are then extracted and the viscous fluid contained

therein is drawn out into a fine uniform line which is stretched between pins at the extremity of a board The board is exposed to the sun till the lines dry and harden. These lines form the silk gut.

Non-textile Uses of Rayon

The method of manufacturing rayon by drawing filaments of a cellulose solution through spinnerets has suggested other uses for it. Thus, if in place of 50 or more orifices in the spinnerets, only one or more larger orifices are provided, the thread spun would be comparatively thicker and would simulate **horse-hair.** Such imitation hair is used for making wigs, etc. Or, in place of thread, **ribbon strips** can be extruded through appropriate orifices. Cellulose solution can also be spread on a rotating engraved roller when only the cavities become filled; the resulting lace-like fabric can then be hardened in a coagulating bath to form artificial tulle. Viscose rayon is now used to a great extent in place of ramie as the foundation for incandescent mantles. It is also spread out as a thin film known as **cellophane** or **viscacelle** which is used as transparent wrapping for food, etc. or which due to its great shrinkage on drying is ideally suited with or without pigmentation as film caps for closing bottles. Cellulose acetate has been found very suitable for insultating electric wires; it is also made into non-inflammable **cinema films**; and, dissolved with butyl or armyl acetate, it is employed as **dope** for air-craft wings to which it gives a shrunk waterproof finish. Nitrocellulose similarly dissolved and mixed with softeners and pigments provides a **lacquer** for motor car bodies and other spray-painted articles; it is frequently mixed with camphor and pigments to provide celluloid sheets and moulded articles or to produce cinematograph films which are however inflammable. The inflammability of cellulose nitrate is indeed taken advantage of in manufacturing gun cotton and other explosives. Lastex yarn is the name given to an elastic yarn produced by twisting two threads of rayon in opposite directions round a core of **Lactron** thread: this thread is produced from latex like rayon, by

extruding it through small apertures in a coagulating bat and subsequent vulcanising. Lastex yarn is used for bathing costumes, corsets, waist bands, tops of socks, etc., in fact, wherever tucking or gripping is desired.

Some Facts about Dyeing

In the dyeing of silk fabrics, the most essential requisite is the fastness of the dye, as these fabrics last for a very long time and are not laundered or ironed as frequently as cotton, linen or other fabrics. The selection of the particular dye is therefore very important, especially as certain colours are 'cold' and others 'warm'. While black and red are warm because these colours absorb the incident light and thus warm the material, white and blue are cold as they do not absorb but reflect light. Sometimes the primary colours, blue, yellow and red, and the secondaries derived from them are regarded as 'cold' or hard while the tertiary colours obtained by mixing the secondaries among themselves or with the primaries are regarded as soft or warm Actually, the primary colours are the most intense and bright. As dyeing increases the value of the silk and soft and novel pastel shades enhance its lustre, the preparation of particular dyes remains a jealously guarded trade secret of the manufacturers evolved through long experiments of trial and error. While natural silk can be dyed with any kind of dye, (basic, acid, substantive, mordant or vat), artificial silk can only be dyed with basic and substantive dyes and acetate silk only with basic dyes in the presence of a mordant Thus, real silk can be distinguished from artificial by boiling with a weak solution of an acid dye and a drop of acid: true silks will be deeply dyed while the rayon will be merely stained and can be washed back. This test can be easily performed as we have already said by immersing the two fibres in diluted red ink.

Tariff Board Report

As continual increases in the importation of raw silk from foreign sources were regarded as a grave menace to

the existence of the indigenous sericultural industry, the Government of India directed the Indian Tariff Board to hold an inquiry as to whether any protection was needed by this industry and if so in what form. The Committee appointed by the Tariff Board issued their comprehensive report in 1933. They were of opinion that the raw silk industry occupied an important place in the economic structure of India and that its protection was desirable in the interests of the agricultural as well as the weaving industry. They also thought that as the handloom weaver was the principal consumer of raw silk, any measure such as an increase in the duty on raw silk which increased the weaver's cost of production would not be justified unless accompanied by an increase in the duties on silk manufactures. They therefore recommended an increase of duty on the imports of raw silk as well as on silk goods and a levy of specific duties on cocoons as well as on artificial silk. Though the margin of increases recommended by them were not adopted, sufficiently high duties were imposed on all these articles. Thus, in place of 50 per cent ad valorem duty recommended on cocoons, the duty levied is 25 per cent plus 14 annas per lb. plus one-fifth of the total duty. The same rate applied to raw silk, silk waste and noils which are further subject to an annual tariff valuation for import purposes. A similar duty subsists on silk yarn except sewing thread on which the duty is 30 per cent ad valorem. On silk fabrics the import duty is 50 per cent ad valorem plus a definite sum ranging from one to two rupees according to the nature of the fabric plus one-fifth of the total duty. These duties are said to be protective and are held to have achieved their object. The exports of raw silk which used to be considerable formerly have now shrunk to about one-tenth of the original quantity on account of its increased consumption in India. The duty on imported rayon yarn is not necessarily protective. In place of the Tariff Board's recommendation of one [illegible] per lb. the duty is 25 per cent ad valorem or 3 annas per lb. whichever is higher plus one-fifth of the total duty.

Our annual imports of raw silk may be reckoned at about 2 million lbs., of silk yarn at about one million lbs , and of silk manufactures at over ten million lbs. We import 30 million lbs of artificial silk yarn for the use of the Indian weaving industry apart from about 20 million lbs of rayon manufactures.

EPILOGUE

The object of publishing this monograph is to supply useful information about Natural and Artificial Silk for the benefit of the general reader. Although the subject is technical in more respects than one, all technical details are avoided and information is collated and compiled in a form intelligible to readers of average intelligence The book is indeed intended for the layman and not for the technician. For the latter and for those whose thirst for knowledge becomes whetted by a perusal of these few pages, there are already available many excellent books dealing alike with sericulture and the silk industry and an extensive literature is growing up in recent years on the rayon industry. There is however no small book which presents from the view-point of India a survey of both real and artificial silk in all its various aspects which the present compilation endeavours to do. For, to India, where the silk rearing and silk weaving industries have become firmly established through ages, whose exquisite fabrics have evoked world-wide admiration and where in spite of the availability of raw materials no attempt at the production of artificial silk yarns largely consumed by our hand and power looms has yet been made, the various problems of silk and Art Silk which form THINGS AROUND US are of vital importance. Among these problems, the improvement in the quality and production of silk, the encouragement of the handloom weaver, the organisation of sericulture on scientific lines, the prevention of disease and wastage, the utilisation of our short staple cotton or of our soft timbers in the production of rayon and so many incidental factors should well engage the attention of every intelligent son of the soil. If these problems are satisfactorily tackled, and they should be in a country proud of her Swadeshi cult, the future of our silk industry is bound to be assured. The tackling of these problems requires a rudimentary knowledge of the production, utilisation and consumption of the two varieties of silk, real and artificial —which it is the object of this manual to provide.

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